ANNEX 2

THE EFFECT OF INTERFERENCE EVENTS ON SERVICE AVAILABILITY

1 Introduction and objective

Service availability for a link in a GSO network is affected by a combination of atmospheric, equipment, and interference events in addition to the time to recover from loss of synchronization lock. This analysis demonstrates that where synchronization recovery time is a consideration, the service availability (defined later) of a GSO network decreases in inverse proportion to the number of propagation, equipment and interference events that cause synchronization loss of lock, even though the composite total of link unavailable time may remain constant, i.e. many short interference events are more detrimental than fewer log term events.

2 Definitions

Recommendation ITU-R S.579-4 defines availability for a hypothetical reference circuit (HRC) and a hypothetical digital telephony path (HRDP) in the FSS. Considering d) and e) of Rec. ITU-R S.579 state that availability is determined by the combined effects of equipment and propagation availability; and, Recommends 4 indicates that unavailability should also take into account equipment recovery time. Recommendation ITU-R S.579 defines circuit "availability" and "unavailability" as follows:

$$\text{Availability} = (100 - \text{Unavailability})\ (\%) \tag{1}$$

where: $$\text{Unavailability} = (\text{unavailable time}/\text{required time}) \times 100\ (\%) \tag{2}$$

and: "required time" is defined as:

the period of time during which the user requires the circuit or digital path to be in a condition to perform a required function and the unavailable time is the cumulative time of circuit or digital path interruptions within the required time.

This analysis takes into account the effects of "sync recovery time" as a function of individual event duration when assuming that the total of all event times are constant over a year long period. Analysis and the numerical examples are all presented on a "per year" basis. The analysis demonstrates that many events of short duration that cause unavailability generally will have a greater impact, over a longer time period, on performance than a few events of long duration over the same longer time period. More study is required to determine what time periods should be selected for evaluation.

3 Availability and user requirements

Recommendation ITU-R S.579-4 relates availability to a user requirement for the performance of a function. Those functions such as those that are concerned about sync loss, will require additional time beyond adequate Carrier to Noise (C/N) restoration to restore the desired functional capability. For those links, the restoration of adequate C/N is followed by reacquisition of link functionally required synchronization that are needed for the provision of service.

For the purposes of this analysis it was found to be useful to distinguish between link availability and user service availability as follows:

Link availability = time when the receiver/demodulator output is available; (3a)

User service availability = time bit synchronization and user function is available. (3b)

Since user service availability depends on link availability, the former can never be greater than the latter.

It also follows from the above that "Link unavailability" and "User service unavailability" are one minus the above values.

Some equipment implementations, beyond the receiver demodulator and bit synchronizer, which are sensitive to synchronization lock and which will require restoration, are listed below. The time to accomplish these actions will degrade user service availability relative to link availability. These include:

- Frame synchronisation
- Security synchronisation
- Interleaver synchronisation
- Error correction decoder synchronisation
- Reinitialization of transmission protocols
- User terminal initialisation.

Other user function that are normally dependent on other links (such as redialing), but which may be affected by the loss of synchronization, is not considered at this time.

4.0 Analysis

4.1 Event duration and number of events per year

The "availability" of a link is usually stated in terms of percentages of time during which specific limits may not be exceeded.

Accordingly then if: p = fraction of time the limit is exceeded; and

p = 1 - .01 x percentage of time available; and if

N = number of events per year causing unavailability; and

D = the average duration of each event (seconds).

Then

$$N \times D = p \times 3.1536 \times 10^7 \quad \text{unavailable second per year} \tag{4}$$

Where: 3.1536×10^7 is the number of seconds in 365 days.

For example "availability" of 99%, 99.9% and 99.99% are often stated requirements for satellite network links. The choice of those performance requirements is dictated by many factors including cost, frequency bands implemented, technology limits and specific service need. For the three cases being considered:

"p" = .01, .001 and .0001; and,

the unavailable time in seconds per year can be determined from equation (4) as follows:

N x D = 315,360 unavailable second for a 99% available network;
31,536 unavailable second for a 99.9% available network; and,
3,153.6 unavailable second for a 99.99% available network.

Experimental information (see Annex 1) indicates that sufficiently high level interference events of 1 sec or longer could cause loss of synchronization of common service functions implemented on satellite links. If it is assumed that the entire unavailability budget is taken up by interference events, and all such events were of one-second duration, then each link could experience up to:

315,360 interruptions per year for the 99% link;
31,536 interruptions per year for the 99.9% link; and
3,536 interruptions per year for the 99.99% link.

For each event causing sync lock loss, a recovery time of "R" seconds is required for each event, after adequate link C/N margin was restored for "S" seconds. The "systems unavailability" for that circuit would be increased by N x (R + S) per year: where N equals the number of yearly interruption events causing sync loss, up to the maximums indicated above.

It follows then that:

Service Unavailability = Link Unavailability + N x (R + S); and

Service Availability % = (100 – (Link Unavailability + N x (R + S))%

Using the above equations an example calculation was performed on links designed to have an availability of 99%, 99.9% and 99.99%. Tables 1, 2 and 3 illustrate the calculated effects of sync recovery time on service availability for the three above link availability examples. In all of these examples it is assumed that:

Recovery Time "R" = 10 seconds; and,

Restoration Time "S" = 1 second.

Figures 1, 2 and 3 provide a graphical illustration of the calculated results.

TABLE 1

Link Availability of 99%

Number of Sync Loss events N	Event Duration "D" secs	N x (R + S) Recovery Time (Sec)	Service Unavailability Time (Sec)	Service availability %
10	31 536	110	315 470	98.999
30	10 512	330	315 690	98.998
100	3 153.6	1 100	316 460	98.996
300	1 051.2	3 300	318 860	98.989
1 000	315.36	11 000	326 360	98.965
3 000	105.12	33 000	348 360	98.895
10 000	31.536	110 000	425 360	98.651
30 000	10.512	330 000	645 360	97.954
100 000	3.1536	1 100 000	1 415 360	95.512
300 000	1.0512	3 300 000	3 615 360	88.536

FIGURE 1 - Effect of Sync Recovery on 99% link Link Availability

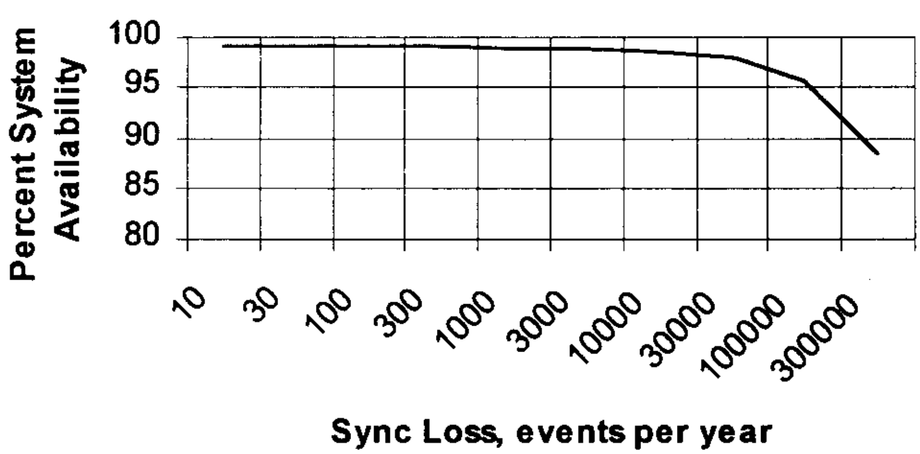


TABLE 2

Link Availability of 99.9%

Number of Sync Loss events N	Event Duration "D" secs	N x (R + S) Recovery Time (Sec)	Service Unavailability Time (Sec)	Service availability %
10	31 536	110	31 464	99.899
30	10 512	330	31 866	99.898
100	3 153.6	1 100	32 636	99.896
300	1 051.2	3 300	34 836	99.889
1 000	315.36	11 000	42 536	99.865
3 000	105.12	33 000	64 536	99.795
10 000	31.536	110 000	141 536	99.551
30 000	10.512	330 000	645 360	97.953

FIGURE 2 - Effect of Sync Recovery on 99.9% Link Availability

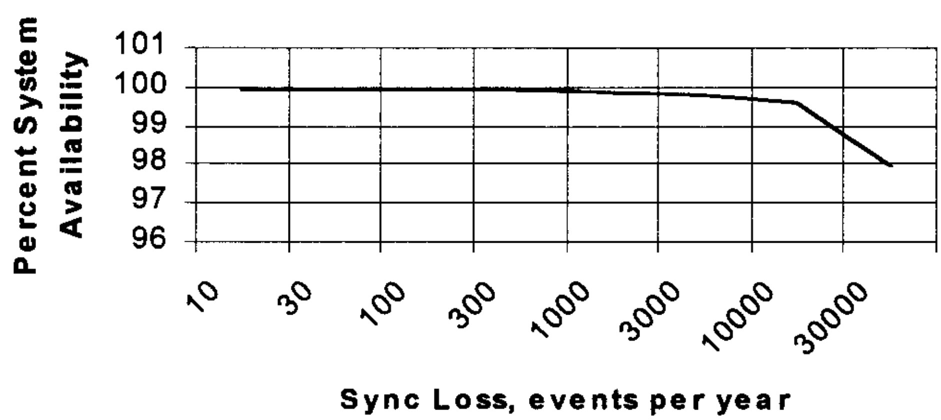
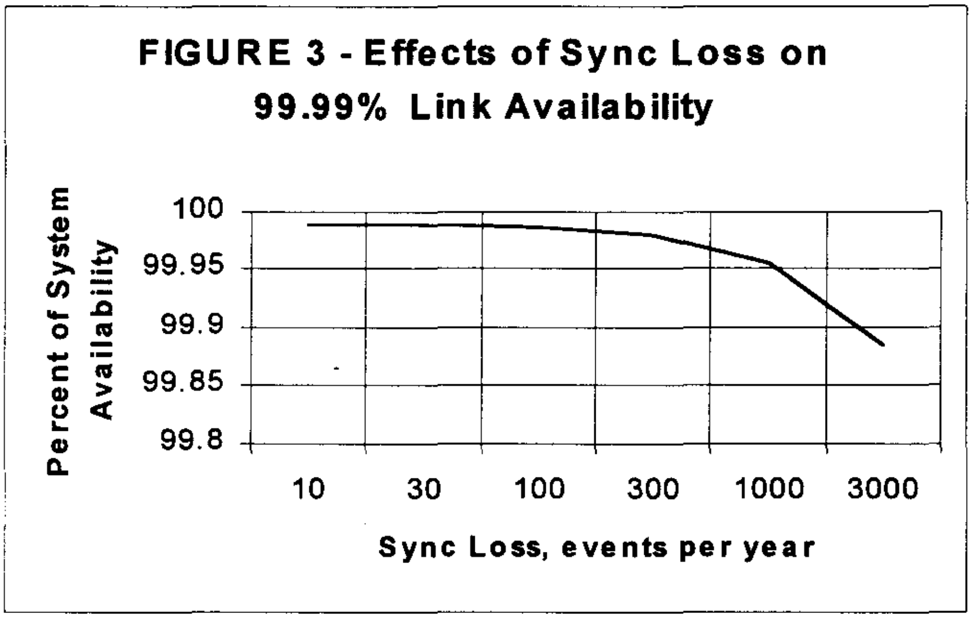


TABLE 3

Link Availability of 99.99%

Number of Sync Loss events N	Event Duration "D" secs	N x (R + S) Recovery Time (Sec)	Service Unavailability Time (Sec)	Service availability %
10	31 536	110	3 263.6	99.989
30	10 512	330	3 483.6	99.986
100	3 153.6	1 100	4 253.6	99.896
300	1 051.2	3 300	6 453.6	99.979
1 000	315.36	11 000	14 153.6	99.955
3 000	105.12	33 000	36 153.6	99.885



5.0 Discussion

Consideration of Tables 1 –3 and Figures 1 – 3 indicate that Sync loss recovery affects the availability of service applications in proportion to the frequency of sync loss even when link availability performance is maintained. It is therefore apparent that control of sync loss causation events is important and that further study to characterize those events is warranted. Past impairment studies have generally dealt with propagation anomalies which have been mostly concerned with the total elapsed time of occurrence of transmission impairments and have presented their results in cumulative distribution form. Other interference studies have been generally concerned with causative interference levels of a relatively steady state nature. It is important to note that Radio Regulation S22 allows provisional equivalent power flux-density (epfd) limits for non-geostationary orbit (NGSO) satellites in certain frequency bands in the fixed-satellite service (FSS).

Characterization of interference from NGSO interference sources should give consideration to the interference environment that will result from the repetitive nature of NGSO orbits. That such considerations are important can be inferred from the orbital mechanics of a single low altitude NGSO satellite. It can be shown that a single low altitude satellite can be implemented to operate in a orbit that will pass over the same point on the earth surface in the order of 1 000 times per year. Considering that multiple satellite NGSO systems will share spectrum with FSS networks there is a concern that the impact of the repetitive nature of those sources of interference are not yet fully understood and must be studied further.

6.0 Conclusions

The requirements of service recovery times in GSO networks should be taken into account when establishing network reliability during link design. An analysis has demonstrates that the recovery time, after a period of unavailability caused by an event, has an impact on service availability of a GSO circuit. The analysis also shows that given constant "link unavailability" the "service availability" of a GSO circuit decreases as the frequency of the sync lock causative events increase. While it is recognized that the distribution of unavailability over a year is important, consideration of the impact of shorter time periods may be the subject of further study.

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WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT NEW RECOMMENDATION: A METHOD FOR EVALUATING EPFD LIMITS FOR SERVICES WHOSE AVAILABILITY ARE SENSITIVE TO SYNCHRONIZATION TIMING RECOVERY IN THE KU BAND

1 Introduction and purpose

At the third meeting to the JTG in Long Beach California NGSO epfd masks were proposed by different administrations including US, France and Intelsat. Those proposed masks were offered as limits, per criteria proposed in section 3 of Recommendation ITU-R S.1323, for protecting GSO networks from NGSO systems sharing the same spectrum. In order to better evaluate the adequacy of those proposed masks the JTG requested in Circular Letter CR/116 that administrations submit information describing sensitive FSS and BSS circuits in the form of link budgets.

Many FSS services are of a digital nature employing sequentially layered and synchronized coding schemes that address security, digital compression, and error correction and service applications. High levels of interference from NGSO systems, presumably corresponding to time allowance for unavailability, or even shorter periods of time could potentially result in the loss of synchronization of GSO communications which may in turn cause extended periods of service outage. The attached Annex proposes a recommendation as to how to calculate sync loss thresholds and evaluate the effects of NGSO epfd limits on GSO network services whose availability are sensitive to synchronization timing. Three methods of estimating sync loss epfd values are given in the attachment. Section 3 estimates the epfd limits needed to protect GSO networks in all rain zones by calculating the theoretical I/N ratio occurring at the sync loss point. Section 4 analyzes the pfd values that are necessary to protect the CR-116 links in the Ku-band. Section 5 computes the increase in sync loss time of a subset of CR116 links due to NGSO interference by applying methodology D [4A/TEMP/47] to three different masks proposed in 4-9-11/TEMP/92. Section 6 adds one dB of margin to the links and computes the increase in sync loss time due to NGSO interference by applying methodology D [4A/TEMP/47] to three different masks.

ANNEX

Proposed Draft New Recommendation:

A Method for Calculating and Evaluating EPFD Limits for Services whose Availability are Sensitive to Synchronization Timing Recovery in the Ku Band

The ITU Radiocommunication Assembly

Considering

a) that the unavailability of satellite networks that may or may not be part of a Hypothetical Reference Digital Path (HRDP) is determined by the combined effects of equipment and propagation availability;
b) that Recommendation ITU-R S.521 specifies that HRDPs can include procedures such as: demodulation/modulation, error correction, buffer and processing which may be implemented in customer terminal or earth station equipment and that satellite networks not part of an HRDP may also be so implemented;
c) that HRDPs and networks not intended as HRDPs may implement the functions described in *considering b)* to provide services, such as MPEG-2, which contain sequentially layered coding schemes that may include among other things: address security, data compression, and error correction;
d) that Recommendation ITU-R S.579 indicates that an HRDP service link, is considered to be unavailable when the received digital signal timing alignment (or synchronization) is lost for 10 consecutive seconds or more. Those 10 seconds are considered to be unavailable time and that period continues until timing alignment (or synchronization) are restored for 10 consecutive seconds;
e) that service links not implemented as an HRDP may consider all lost synchronization time as being unavailable;
f) that Recommendation ITU-R 579 defines Availability and Unavailability of an HRDP link (which may include elements of *considering b)* as:

Unavailability = (unavailable time/required time) x 100%

Availability = (100% - unavailability);
g) that the definitions for Unavailability and Availability in *considering f)* can also apply to links not intended as HRDPs;
h) that the carrier to noise level at which synchronization loss may occur may be in the order of 2 dB less than the target availability operating level carrier to noise level for carriers.

recommends

1. That care be taken in establishing GSO network interference synchronization loss threshold levels;

2. That the establishment and evaluation of synchronization loss threshold levels should take into account the three analytical methods described in the attachment,

NOTE 1 - The time duration and frequency of occurrence of interfering signals can contribute to the determination of the allowable maximum interference level. It is observed that multiple short interference events can result in a larger increased period of unavailability than fewer long events.

This effect and the results of short duration (< 1 sec) interference events are subjects of further study.

ATTACHMENT

This attachment analyzes a family of sensitive links with respect to candidate epfd limits to protect against masks for the purpose of evaluating and determining the optimum level of protection against loss of synchronization.

1 Results

Section 3 of this document describes a method of calculating epfd limits needed to protect GSO networks in all rain zones using the I/N ratio occurring at the sync loss point. The results are parametrically presented in table 3.1. Section 4 computes the pfd values that are necessary to protect the selected CR-116 links in table 4.1-1 for the Ku-band. Section 5 applies methodology D [4A/TEMP/47] to those links by using three different masks and computes the resulting increase in sync loss time. Section 6 adds 1 dB of margin to the links and repeats the analysis as in Section 5. Section 5 and 6 identify which of the limits provide the most protection against synchronization loss.

2 Sensitive link budgets

The approach used in developing the link budgets being considered in this document was restricted to circuits that could be served by existing space segments; and, then selecting earth station parameters that resulted in sensitive configurations which could be served by those space segments. The list of earth station parameters that were considered in the selection and design of the link included geographic and rain zone location, services that might be provided and specific carrier modulations. Bandwidth efficient modulation systems such as 16QAM and 8PSK and power efficient modulations such as QPSK R3/4 and R1/2 were used where appropriate; and, were matched to appropriate earth station antenna sizes. Operating settings for the links such as attenuation steps and transponder back off were selected from within the usual range that was available in the selected space segment. Operational links that were finally chosen for evaluation were selected on the basis of their expected sensitivity to interference. Those links were considered to be sensitive if, among other things, they had low clear sky operating margins with low system noise temperatures. All link budgets selected were for transparent space segments and, accordingly, had both up-link and downlink segments. Some selected up-links were chosen to operated in the C bands or had power control as is common in practice. This analysis assumes that NGSO systems are creating interference at the maximum levels allowed by the epfd mask at locations on the earth's surface. This worst-case assumption may over-estimate the frequency of NGSO interference on sync loss. Even though this analysis considered sensitive links, it should be understood that sync loss can occur anywhere in the world where rain attenuation can exceed the provided margin.

The link budgets modeled and presented for this analysis represent a fraction of possible sensitive links in terms of the numbers or types that might actually exist.

In developing the selection of link budget, availability was a variable that was used to minimize excess margin in the links within the constraint that availability could not exceed 99.99%. These availability's selected, were calculated using Methodology D as described in S.1323 [4A/TEMP/47].

3 Theoretical Sync Loss epfd Calculation

Sensitivity to synchronization loss due to rain is a global problem to GSO networks and NGSO interference will increase the probability of sync loss in all rain zones. Since GSO networks are designed to reduce synchronization losses to near zero percent of the time, additional interference from NGSO systems that cause sync loss is unacceptable.

A simplified calculation can be performed to demonstrate the issues and epfd limits needed to protect GSO networks in all rain zones and can be estimated by calculating the I/N ratio occurring at the sync loss point. The calculation depends on the received carrier to noise ratio $(C/N)_{sync\ loss}$ at which sync loss occurs. $(C/N)_{sync\ loss}$ is typically in the range of 1 to 4 dB below $(C/N)_{required}$ for the BER performance of the link. Table 3-1 shows the $(C/N)_{required}$ and $(C/N)_{sync\ loss}$ for various modulation/coding and BER performance. Previous measurements (see [WP4B/TEMP/30]) have shown that a loss of margin of 2.2 dB below the design availability point will cause loss of synchronization. In order to simplify the calculations, $(C/N)_{sync\ loss}$ was set to 2.2 dB below the $(C/N)_{required}$.

TABLE 3-1

Variation of Modulation and C/N

Modulation	**Coding**	**BER (data rate)**	**$(C/N)_{req}$**	**$(C/N)_{sync\ loss}$**	**$\Delta(C/N)$**	**Reference**
QPSK	1/2 + RS	10^{-6}	3.7	2.5	1.2	Modem Spec
QPSK	3/4 + RS	10^{-6}	7	6.1	0.9	4-9-11/TEMP/50
QPSK	3/4	10^{-6}	9	6.1	2.9	4-9-11/TEMP/50
8PSK	2/3 + RS	10^{-10}	12.7	9.8	2.9	Modem Spec
16QAM	3/4 + RS	10^{-10}	13.3	12.2	1.1	Modem Spec

Then under clear sky conditions, the interference power necessary to cause sync loss is given by equation 3-1.

$$10\log\left(\frac{N+I}{N}\right)_{\substack{clear\ sky\\ sync\ loss}} = M_R(dB) + \left(\frac{C}{N_1}\right)_{req}(dB) - \left(\frac{C}{N_2}\right)_{sync\ loss}(dB) = M_R(dB) + 2.2\ dB \qquad (3\text{-}1)$$

where:

M_R = rain margin (dB),

$N_1 = KT_1B$ = total received earth station system noise power (W),

$N_2 = N_1 + I$,

B = transmission bandwidth (Hz),

K = Boltzman's constant,

T_1 = system noise temperature (Kelvins), including interference from polarisation isolation, other GSO's, other NGSO's, and the fixed service,

T_R = receiver temperature,

$T_{other\ GSO}$ = received interference power from other GSO systems under fading conditions of sync loss,

T_{pol} = received interference power from polarization isolation under fading conditions of sync loss,

T_{fs} = received interference power from fixed service systems under fading conditions of sync loss.

From equation 3-1, the interference level to cause sync loss is a function of the rain margin, M_R, which in turn is a function of the location of the GSO earth station. Individual links must be considered in order to set the epfd limits that protect GSO FSS systems from sync loss. This detailed analysis of specific links is performed in Section 4.

Given a rainfade equal to M_R, the following can be derived,

$$10\log\left(\frac{N + I\times 10^{0.1\alpha}}{N}\right) = 2.2\ dB \qquad (3\text{-}2)$$

where:

α = fading on the interfering path (dB).

There are two types of fading scenarios (an uplink fade and a downlink fade) that can occur in a transparent satellite link and can affect the satellite downlink. The first is an uplink fade. Since the uplink and downlink are generally separated, the downlink interference can be assumed to be unfaded when an uplink fade occurs on the desired link. The second is a downlink fade. When there is a downlink fade, the interfering signal can be assumed to be faded by the same amount as the desired signal. In order to specify α, when there is a downlink fade, specific links must be considered. Specific links from CR-116 are evaluated in Section 4.

In the case of an uplink fade, equation 3-2 with $\alpha = 1$ can be used to determine the epfd limits required to protect GSO FSS links against sync loss. It is assumed that sync loss will only occur during an NGSO inline event. An inline event occurs when a NGSO is directly between a GSO and GSO earth station area and the NGSO side beam enters the GSO main beam. For the inline event, the epfd is the same as a pfd and is given by equation 3-3.

$$epfd = \left(10\log(I) - 10\log\left(\eta\times\frac{\pi D^2}{4}\right)\right) \qquad (3\text{-}3)$$

where: I is determined from equation 3-2,

D = earth station diameter (m),

η = antenna efficiency.

An example is given below using equation 3-1 and 3-2.

Example: Given an earth station with a 10 m antenna, system noise temperature of 400 K, a 4kHz bandwidth and an operating availability of 99.9%. The ITU 618-5 rain model in rain zone E, at a latitude of 40 degrees, and a downlink frequency of 12 GHz, gives a required rain margin of 2.22 dB necessary to operate for the given availability. Then

$$10\log\left(\frac{N+I}{N}\right) = 10\log\left(1+\frac{I}{N}\right) = M_R + 2.2\ dB = 2.22 + 2.2\ dB,$$

$$1+\frac{I}{N} = 10^{\left(\frac{2.22}{10}\right)} = 2.767 \text{ and } I = 1.767\times N,$$

$$N = KTB = -228.6 + 10\log(400) + 10\log(4000) = -166.6 \text{ (dBW)},$$

$$I = 10\log(1.767) + (-166.6) = -164.1\,(dBW/m2/4kHz),$$

$$epfd = \left(-164.1 - 10\log\left(0.65 \times \frac{\pi \times 10^2}{4}\right)\right) = -181.2\,(dBW/m2/4kHz).$$

Table 3-1 shows epfd values for sync loss independent of the downlink frequency for various levels of temperatures, earth station sizes, and an efficiency of 0.65. This describes the situation where there is an uplink fade and the downlink is not faded, thus the interfering signal is not faded.

The results in Table 3-1 are parametric as a function of temperature and antenna diameter. The received temperatures are typical values found in the CR-92 and 116 link budgets. Since sync loss is assumed to only occur during an inline event, this type of interference disregards GSO earth station antenna discrimination and therefore is GSO earth station antenna size independent. The limit agreed upon to protect against sync loss must be independent upon earth station antenna size. Therefore, one number must protect all GSO earth stations.

TABLE 3-1

EPFD Values for Sync Loss (dBW/m2/4kHz)

Temp (K) / D (m)	0.6	1.2	1.8	3	7	10	11	13	15	19
300	-162.3	-168.3	-171.8	-176.2	-183.6	-186.7	-187.5	-189.0	-190.2	-192.3
400	-161.0	-167.0	-170.6	-175.0	-182.3	-185.4	-186.3	-187.7	-189.0	-191.0
500	-160.0	-166.1	-169.6	-174.0	-181.4	-184.5	-185.3	-186.8	-188.0	-190.1
600	-159.2	-165.3	-168.8	-173.2	-180.6	-183.7	-184.5	-186.0	-187.2	-189.3
700	-158.6	-164.6	-168.1	-172.6	-179.9	-183.0	-183.8	-185.3	-186.5	-188.6
800	-158.0	-164.0	-167.5	-172.0	-179.3	-182.4	-183.3	-184.7	-186.0	-188.0
900	-157.5	-163.5	-167.0	-171.5	-178.8	-181.9	-182.8	-184.2	-185.4	-187.5
1000	-157.0	-163.1	-166.6	-171.0	-178.4	-181.5	-182.3	-183.7	-185.0	-187.0
1100	-156.6	-162.6	-166.2	-170.6	-178.0	-181.1	-181.9	-183.3	-184.6	-186.6
1200	-156.2	-162.3	-165.8	-170.2	-177.6	-180.7	-181.5	-183.0	-184.2	-186.3
1300	-155.9	-161.9	-165.4	-169.9	-177.2	-180.3	-181.2	-182.6	-183.8	-185.9
1400	-155.6	-161.6	-165.1	-169.5	-176.9	-180.0	-180.8	-182.3	-183.5	-185.6
1500	-155.3	-161.3	-164.8	-169.2	-176.6	-179.7	-180.5	-182.0	-183.2	-185.3

In the spirit of cooperation, the maximum earth station epfd level proposed at the ITU Long Beach meeting accepted a level of −176 dBW/m2/4kHz for a 10-meter earth station. This was based on an assumption that the earth station had a 1000 degree system noise temperature, was experiencing a downlink fade in rain zone E and had an availability requirement of 99.99%. It was assumed at that meeting that earth stations greater than 10 meters would be protected by coordination.

4 EPFD Values to Protect CR-116 Links

As mentioned in the previous section, two scenarios require specific link budgets to determine the sync loss epfd values to protect GSO FSS links. The first case is clear sky (Equation 3-1) and the second case is during an uplink rain fade (equation 3-2). During a downlink rain fade, the fade on the interfering link is assumed to be the same as the desired link. In this section a subset of CR-116 links are evaluated in order to determine the sync loss level by using Equation 3-3. This section bounds the problem because during clear sky the rain margin is protection for the GSO and during an uplink fade, the desired signal is faded, but the interfering signal is not faded. Thus this section bounds the problem.

4.1 Sync Loss PFD Limits for Clear Sky and Rain Fade

The pfd values necessary to protect the links from sync loss during clear sky and rain are given in figures 4.1-1 to 4.1-6. The x-axis identifies the specific carrier in the set of links under analysis. For that set of links there is, in general, about a 4-dB difference between the clear sky pfd and the rain pfd. Table 4.1-1 contains the mean and standard deviation clear sky and rain values for the six earth station antenna sizes selected to be representative of the universe of earth stations that might be served by the test links.

TABLE 4.1-1

Mean and Standard Deviation for Clear Sky and Rain

Antenna Size (m)	Mean (clear) (dBW/m2/4kHz)	Std Dev (clear)	Mean (rain) (dBW/m2/4kHz)	Std Dev (rain)
0.6	-161	0.96	-164	0.39
1.2	-165	1.3	-169	0.40
1.8	-169	1.6	-173	0.40
3	-172	1.7	-176	1.2
7	-177	3.0	-181	2.0
10	-178	3.0	-182	2.6

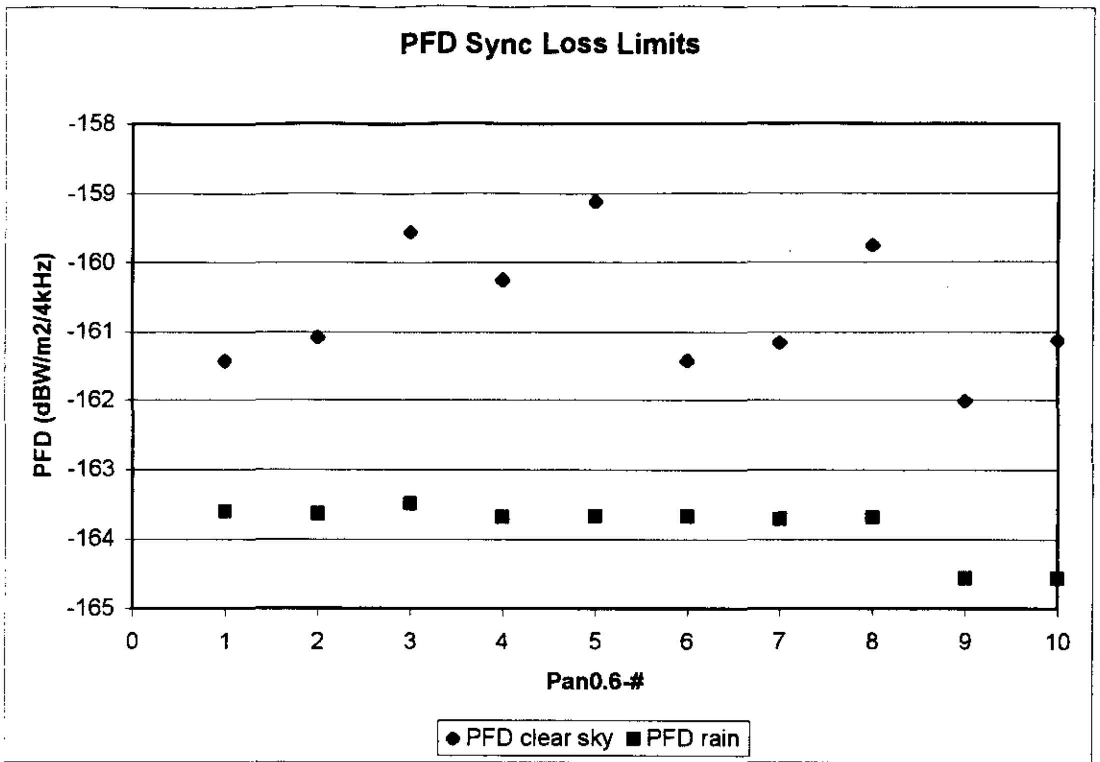

FIGURE 4.1-1\

PFD Sync Loss Limits for 0.6 m Antenna

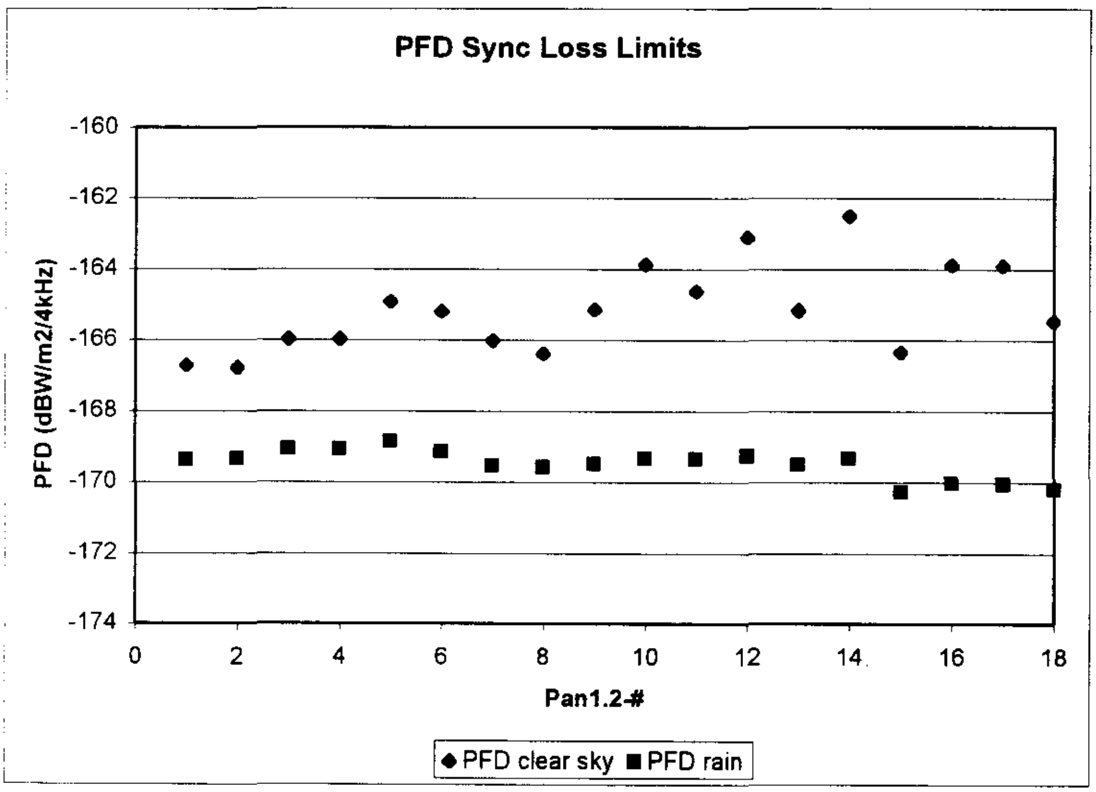

FIGURE 4.1-2

PFD Sync Loss Limits for 1.2 m Antenna

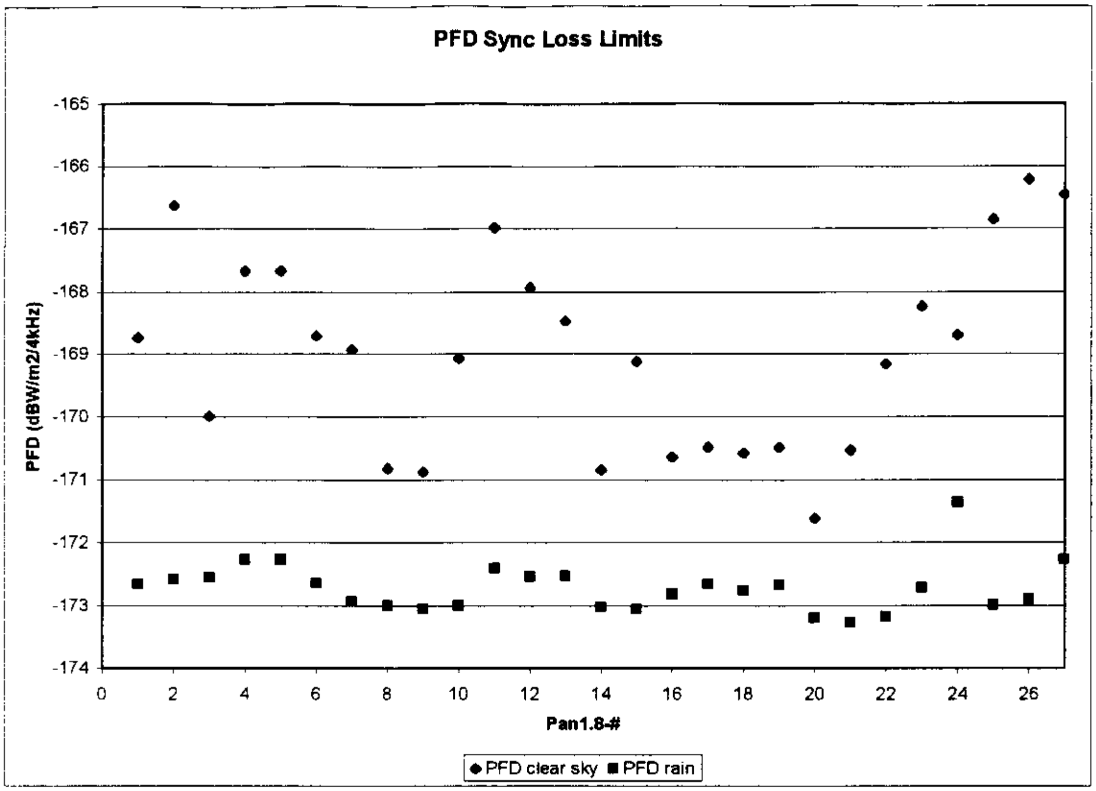

FIGURE 4.1-3:

PFD Sync Loss Limits for 1.8 m Antenna

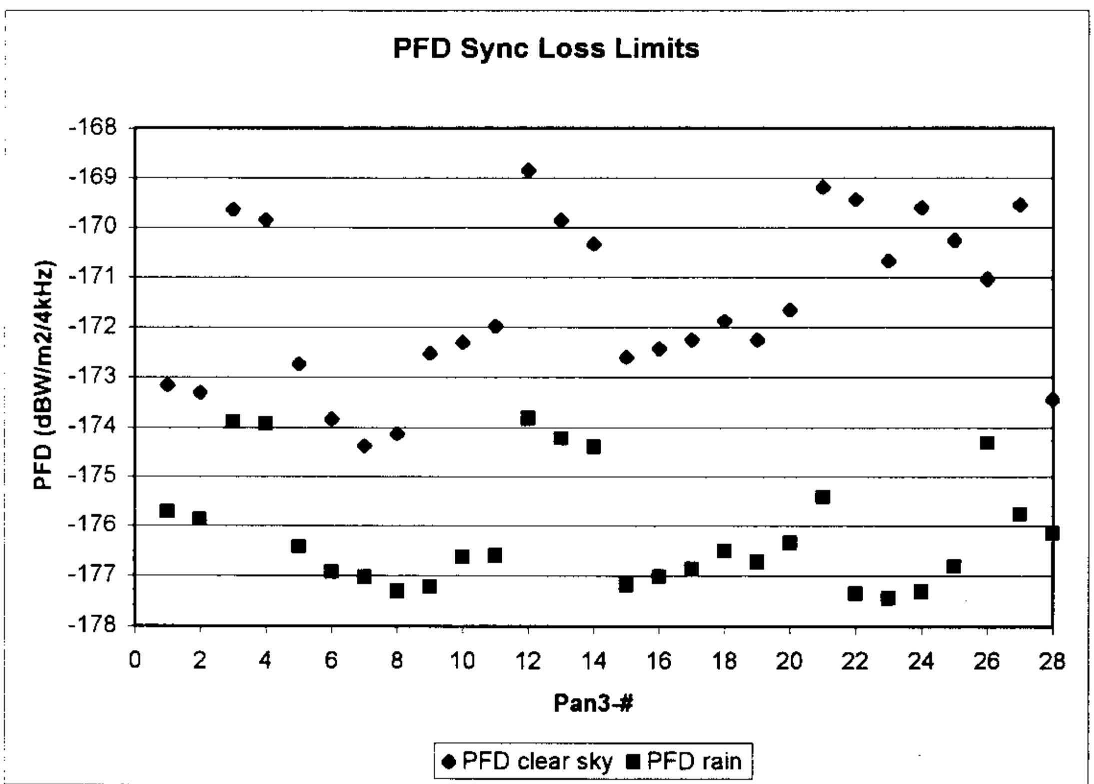

FIGURE 4.1-4

PFD Sync Loss Limits for 3 m Antenna

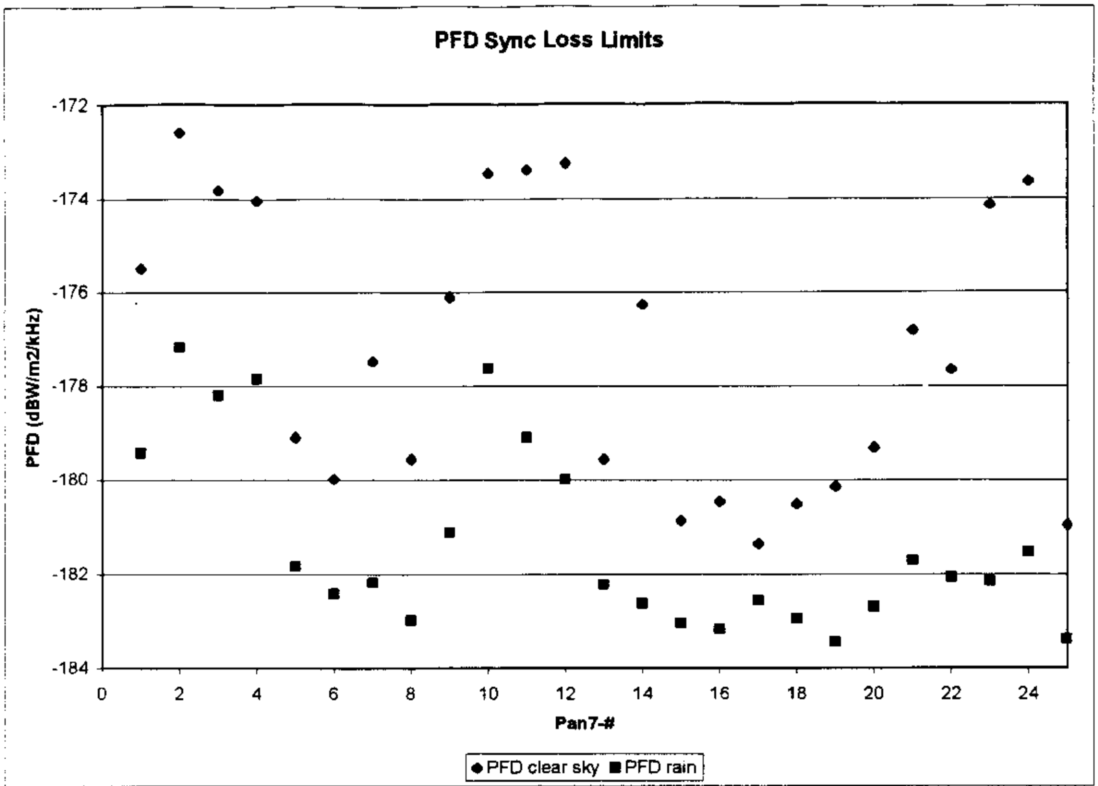

FIGURE 4.1-5

PFD Sync Loss Limits for 7 m Antenna

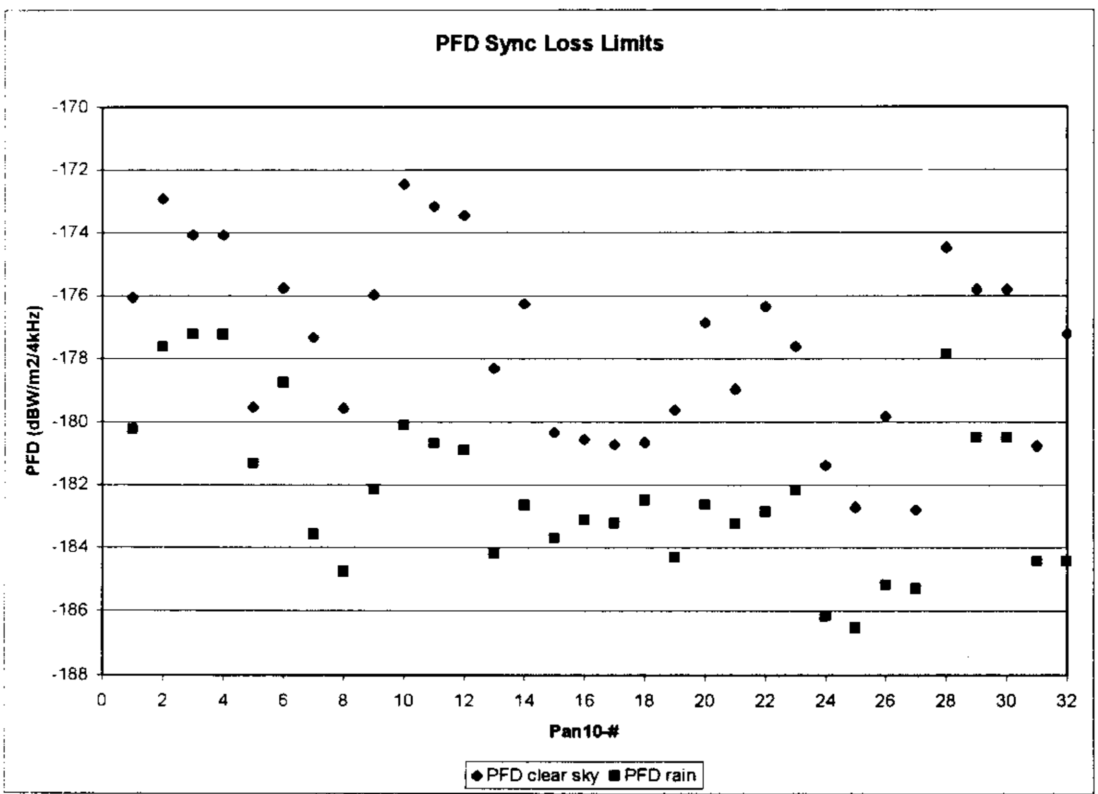

FIGURE 4.1-6:

PFD Sync Loss Limits for 10 m Antenna

5 Increase in Sync Loss Time due to NGSO Interference

Several administrations proposed epfd limits to protect GSO networks in the presence of NGSO systems sharing the same spectrum in the Ku frequency bands. These limits are recorded in [JTG 4-9-11/TEMP/92][in the proceedings leading to WRC2000]. For this analysis those limits are tested using Methodology D, as defined in ITU-R S.1323, to show how the limits affect the sync loss time. The program performs both uplink and downlink fading and accurately calculates the impact of the epfd limits. The threshold C/N sync loss level was calculated for all of the test link budgets. This threshold value is used in the Methodology D procedure where the availability is computed with and without NGSO interference levels present. The unavailability for each link with and without NGSO interference can then be determined and then converted into hours per year. From that information the change in sync loss outage time per year can be determined and its effects analyzed.

To simplify the work the analysis does not include the extended outage time due to reacquiring sync.

Three proposed epfd masks were used in this analysis. These masks were proposed by different administrations. The masks are compared below for selected earth station antenna size.

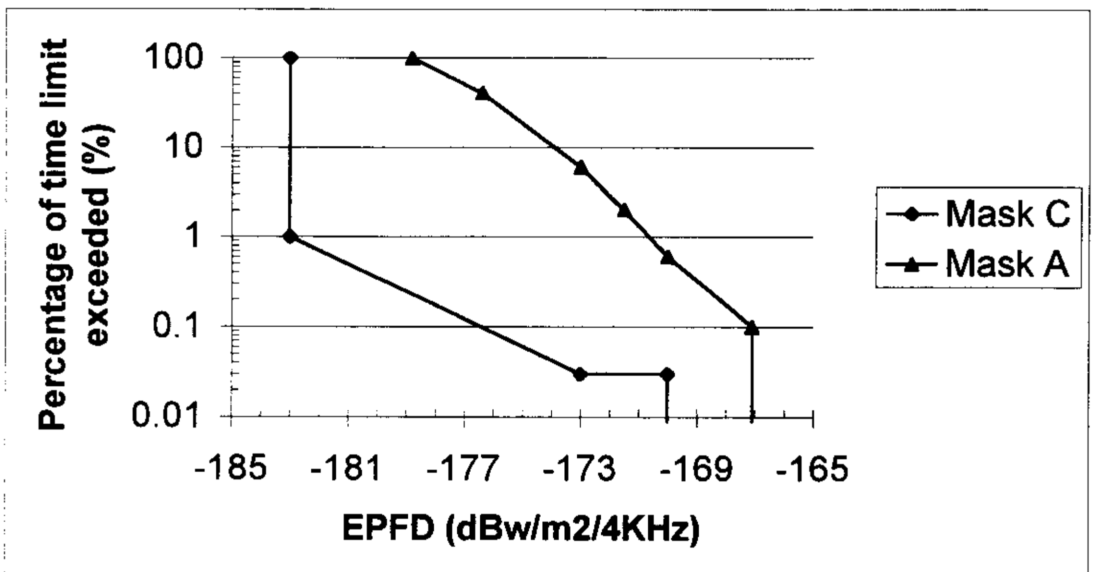

FIGURE 5-1

0.6 m Masks

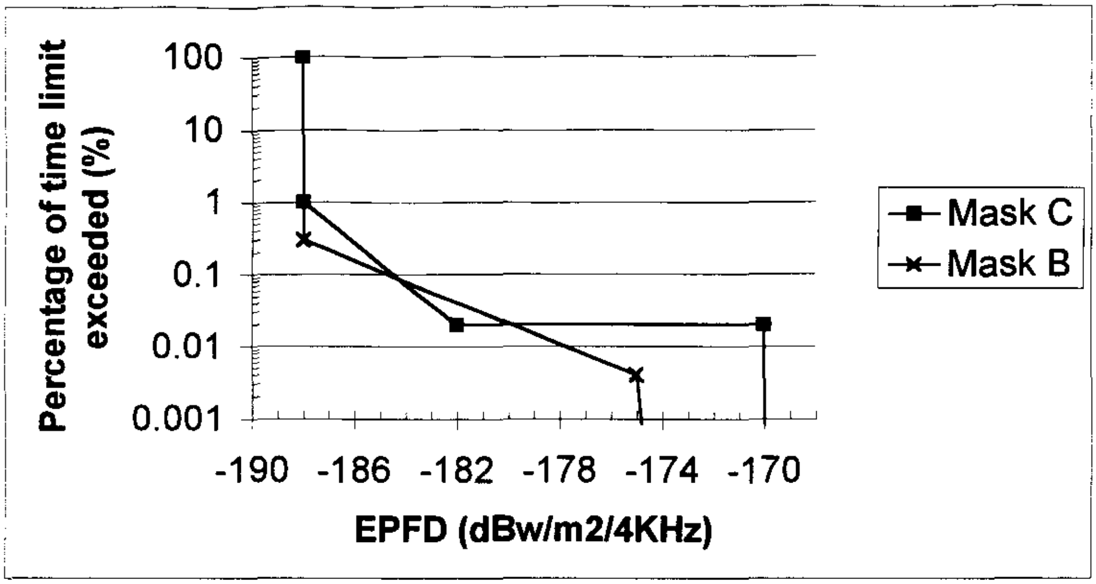

FIGURE 5-2:

1.2 m Masks

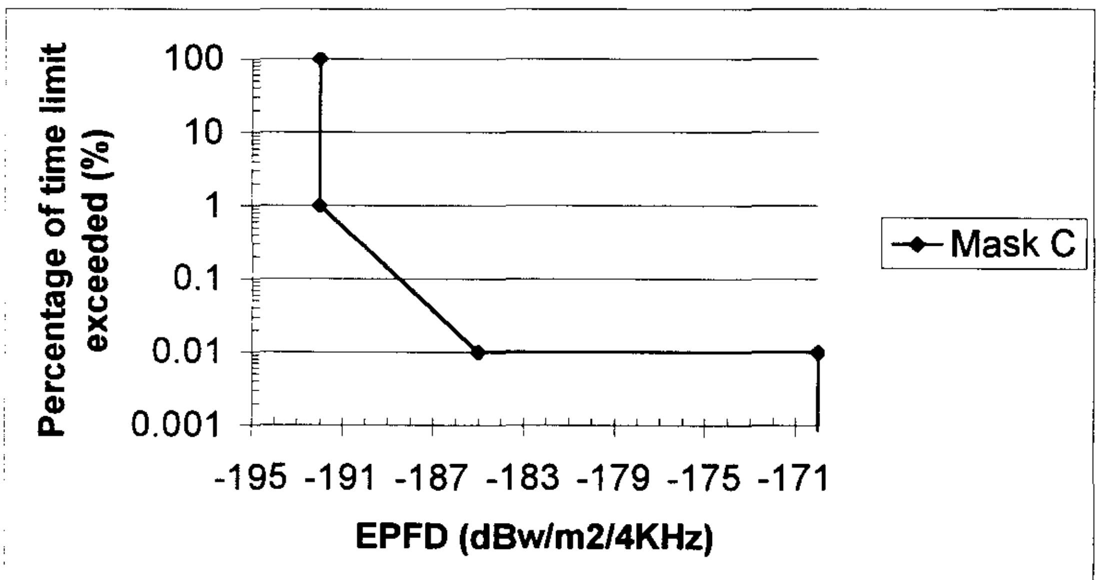

FIGURE 5-3

1.8 m Mask

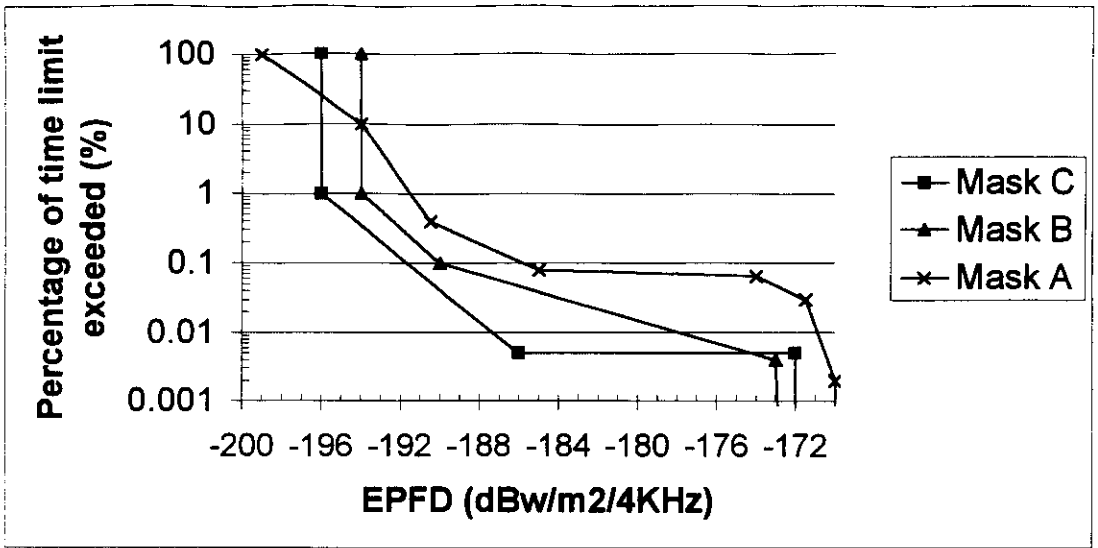

FIGURE 5-4:

3 m Masks

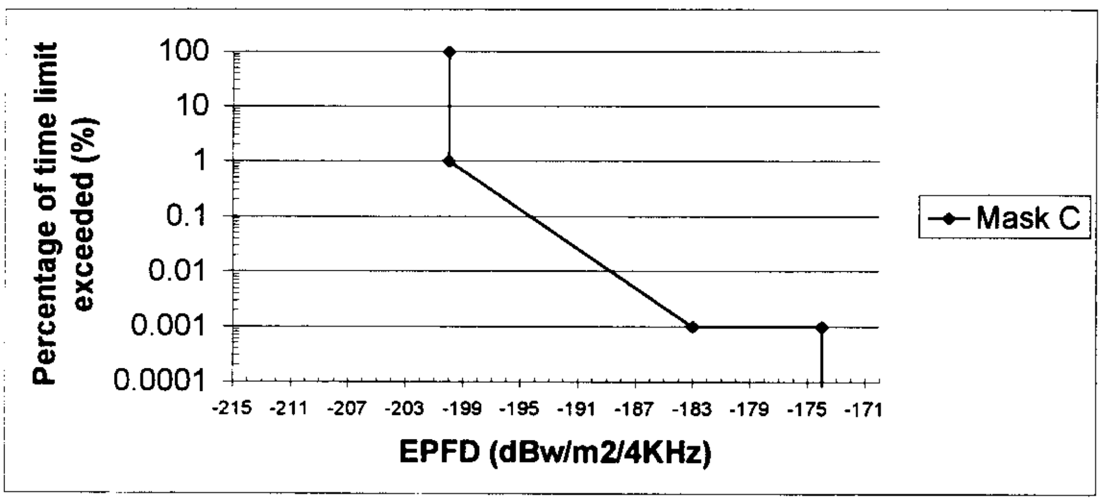

FIGURE 5-5

7 m Mask

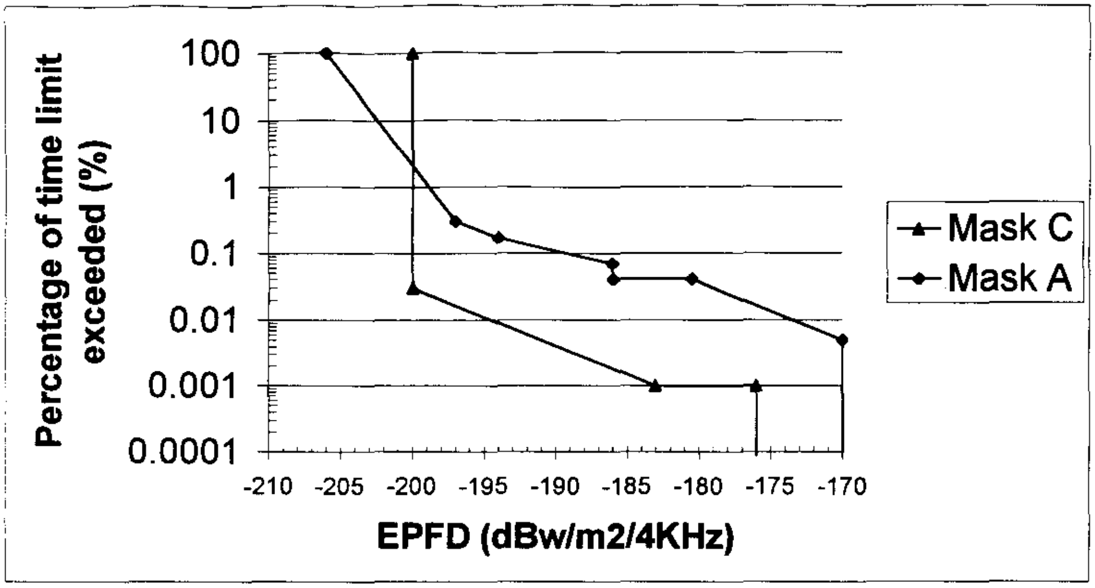

FIGURE 5-6

10 m Masks

5.1 Analysis A

The first proposal suggested epfd limits for three antenna sizes – 0.6 m, 3 m, and 10 m.

Figures 5.1-1 through 5.1-3 show the change in percentage between sync loss time with and without NGSO interference on the primary y-axis. On the secondary y-axis, the total sync loss outage time per year is shown with NGSO interference.

The change in sync loss outage time due to NGSO interference as a percentage is computed in equation 5.1-1.

$$\%\,Change = \left(\frac{Time_{rain+NGSO} - Time_{rain}}{Time_{rain}} \right) \times 100 \qquad (5.1\text{-}1)$$

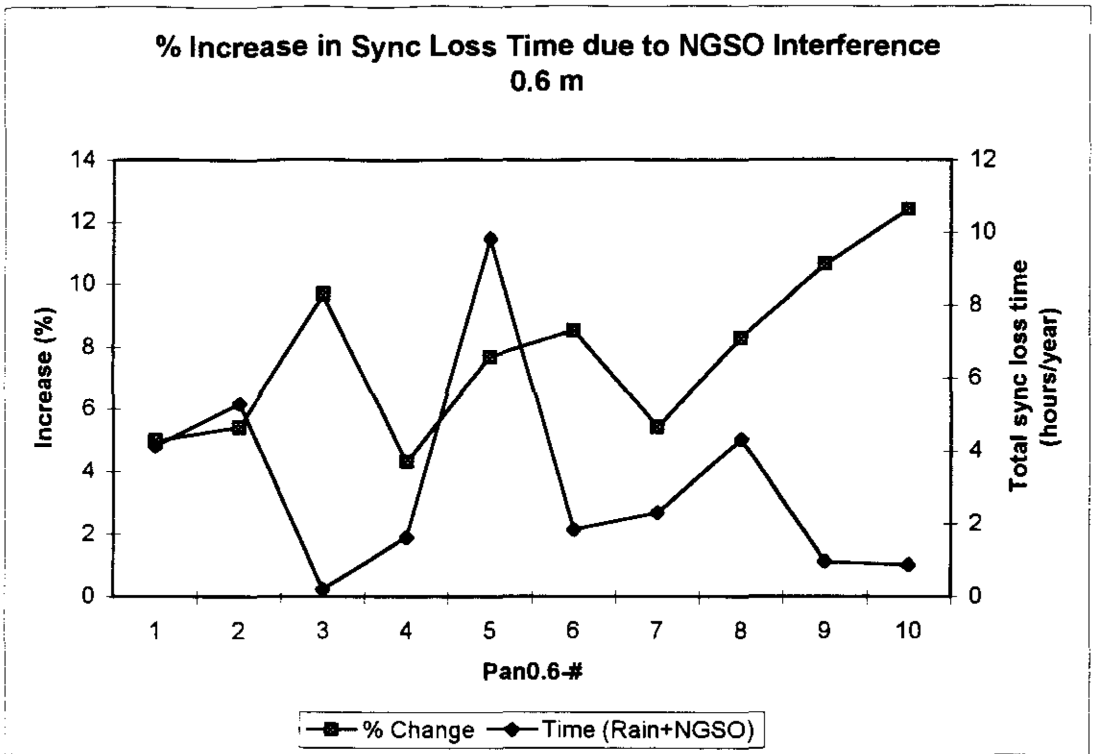

FIGURE 5.1-1

Increase in Sync Loss Time for 0.6 m Antenna

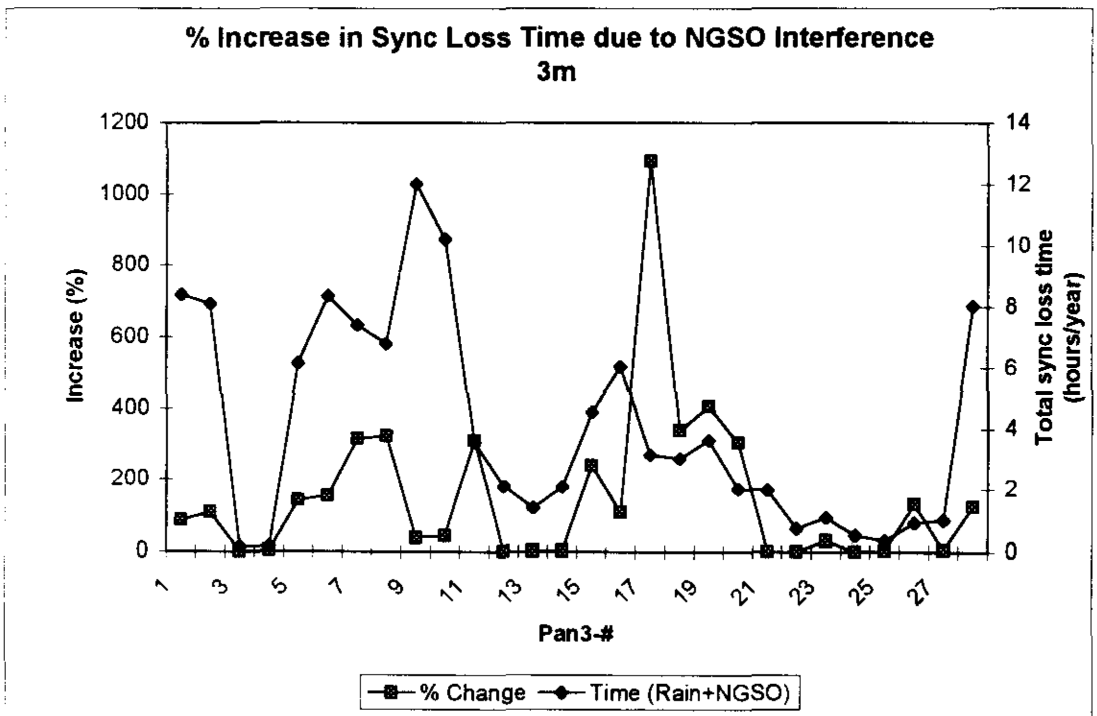

FIGURE 5.1-2:

Increase in Sync Loss Time for 3 m Antenna

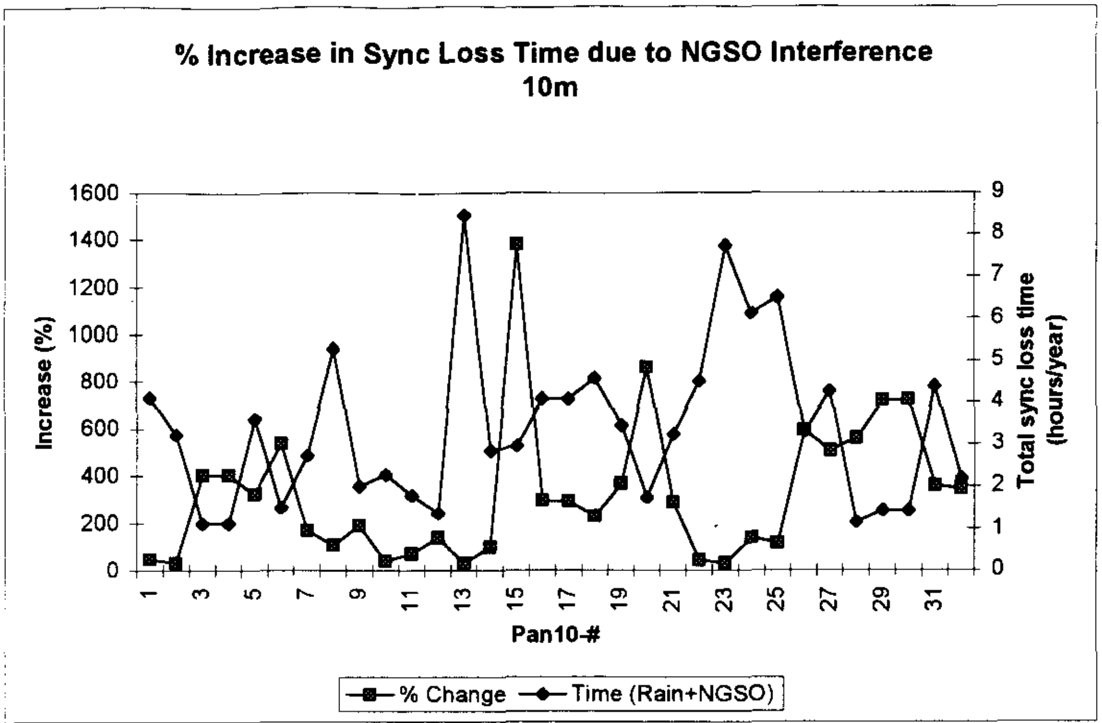

FIGURE 5.1-3

Increase in Sync Loss Time for 10 m Antenna

Table 5.1-1 shows the mean and standard deviation for the change in sync loss outage time with and without NGSO interference and total sync loss outage time due to NGSO interference.

TABLE 5.1-1

Mean and Standard Deviation for %Change and Time

Antenna Size	Mean (%change)	Std Dev (%change)	Mean (hours/year)	Std Dev (hours/year)
0.6	7.74	2.69	3.14	2.88
3	155	226	4.07	3.43
10	325	308	3.41	1.95

5.2 Analysis B

The proposal suggested epfd limits for three antenna sizes – 1.2 m, 3 m, and 8 m.

Figures 5.2-1 through 5.2-2 show the change in percentage between sync loss time with and without NGSO interference on the primary y-axis. On the secondary y-axis, the total sync loss outage time per year is shown with NGSO interference.

The change in sync loss outage time due to NGSO interference as a percentage is computed in equation 5.2-1.

$$\% \, Change = \left(\frac{Time_{rain+NGSO} - Time_{rain}}{Time_{rain}} \right) \times 100 \qquad (5.2\text{-}1)$$

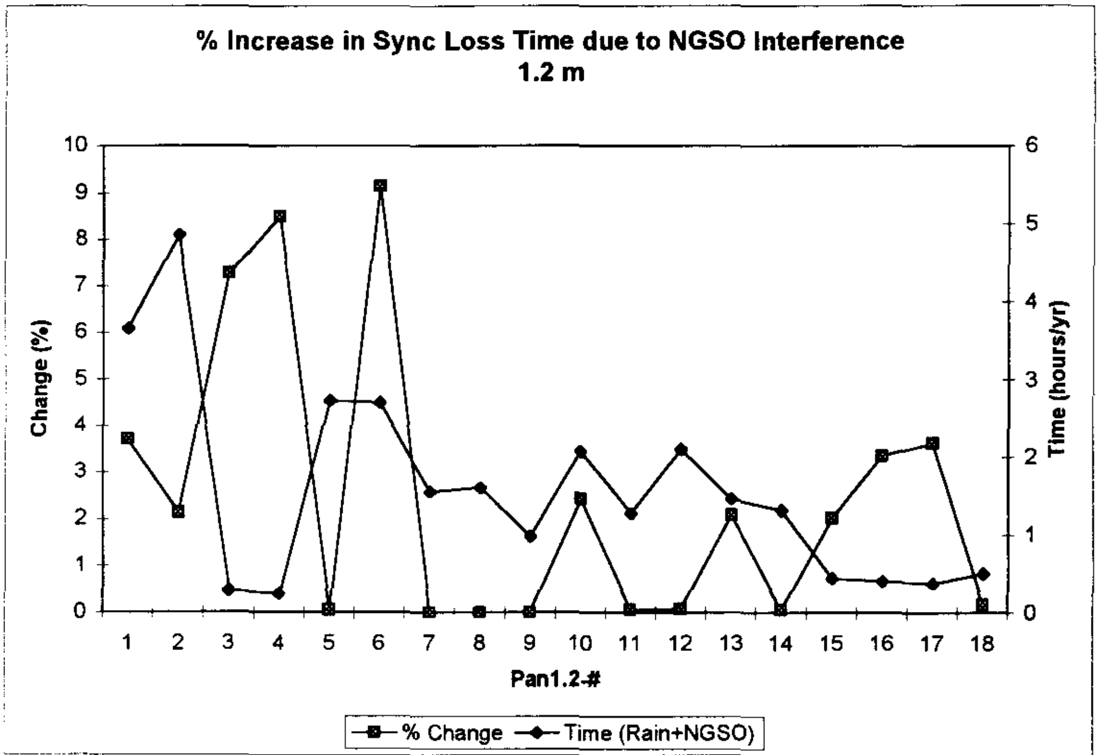

FIGURE 5.2-1

Increase in Sync Loss Time for 1.2 m Antenna

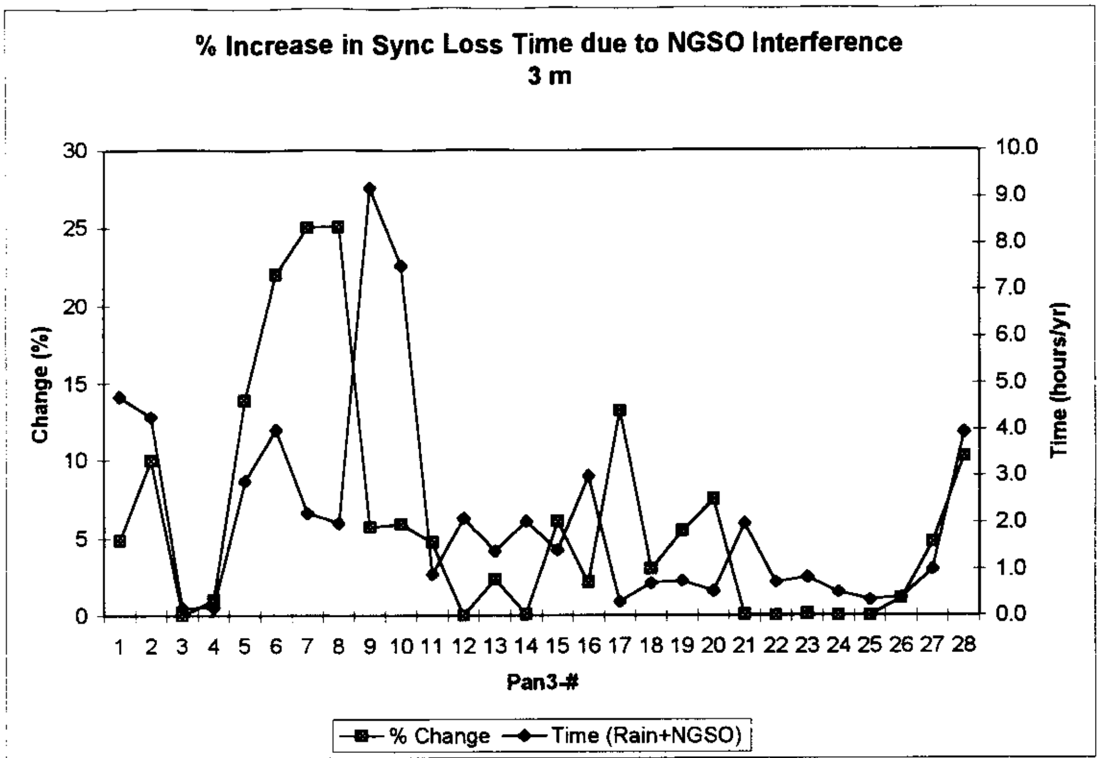

FIGURE 5.2-2

Increase in Sync Loss Time for 3 m Antenna

Table 5.2-1 shows the mean and standard deviation for the change in sync loss outage time with and without NGSO interference and total sync loss outage time due to NGSO interference.

TABLE 5.2-1\

Mean and Standard Deviation for %Change and Time

Antenna Size	Mean (%change)	Std Dev (%change)	Mean (hours/year)	Std Dev (hours/year)
1.2	2.49	3.02	1.59	1.27
3	6.24	7.47	2.15	2.21

5.3 Analysis C

The third proposal suggested epfd limits for six antenna sizes – 0.6 m, 1.2 m, 1.8 m, 3 m, 7 m, and 10 m.

Figures 5.3-1 through 5.3-6 show the change in percentage between sync loss time with and without NGSO interference on the primary y-axis. On the secondary y-axis, the total sync loss outage time per year is shown with NGSO interference.

The change in sync loss outage time due to NGSO interference as a percentage is computed in equation 5.3-1.

$$\%\,Change = \left(\frac{Time_{rain+NGSO} - Time_{rain}}{Time_{rain}}\right) \times 100 \qquad (5.3\text{-}1)$$

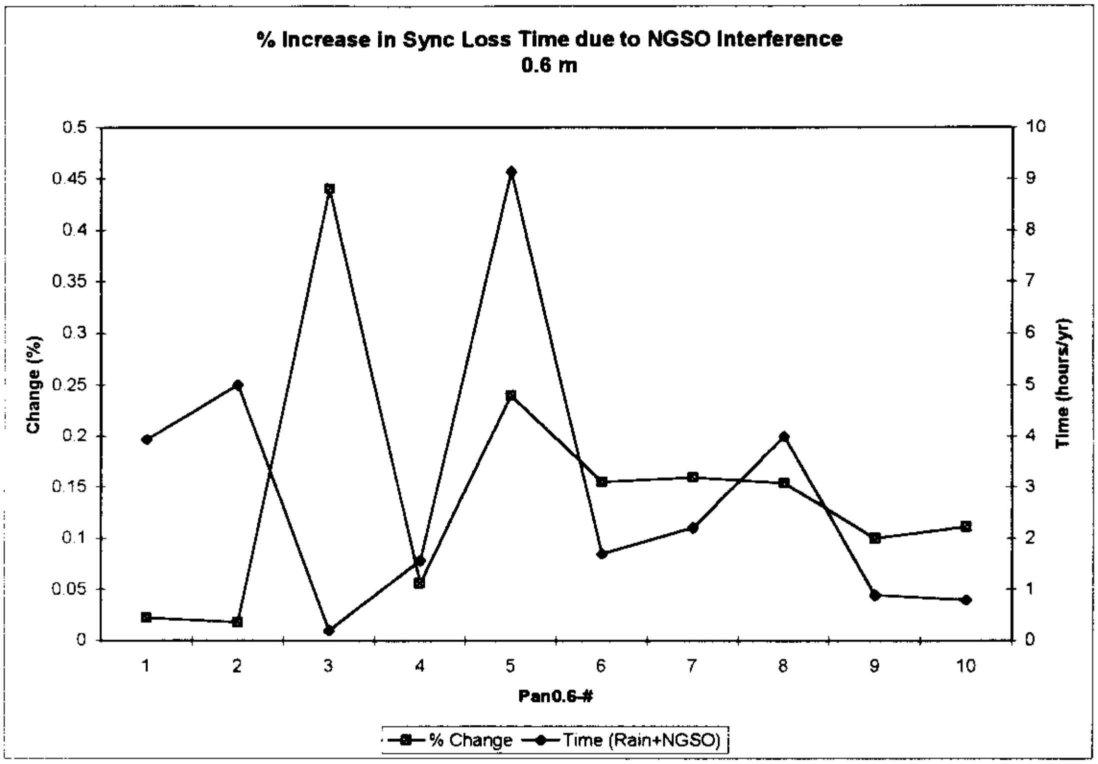

FIGURE 5.3-1

Increase in Sync Loss Time for 0.6 m Antenna

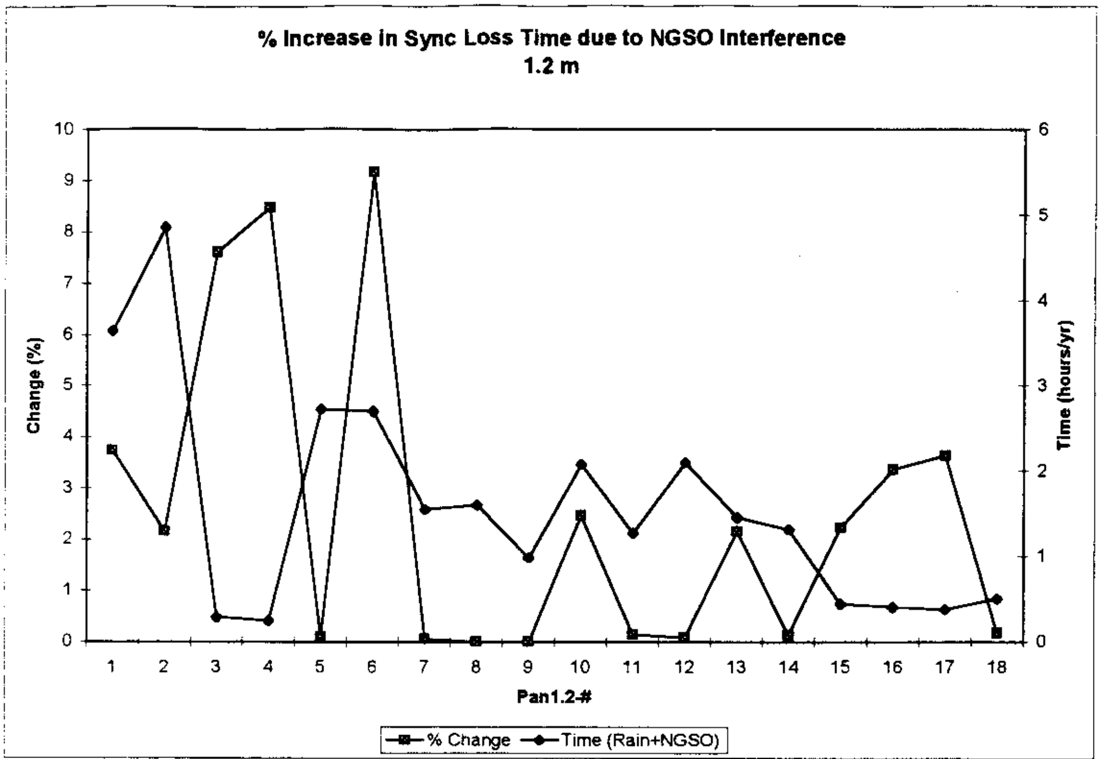

FIGURE 5.3-2

Increase in Sync Loss Time for 1.2 m Antenna

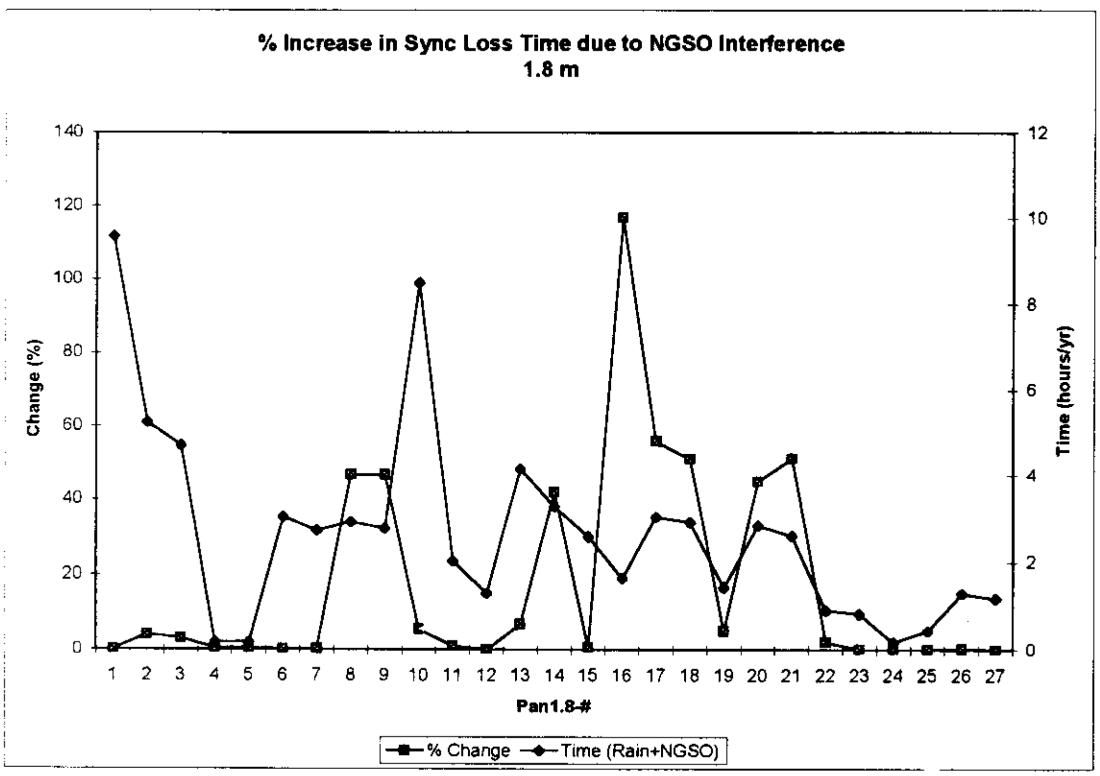

FIGURE 5.3-3

Increase in Sync Loss Time for 1.8 m Antenna

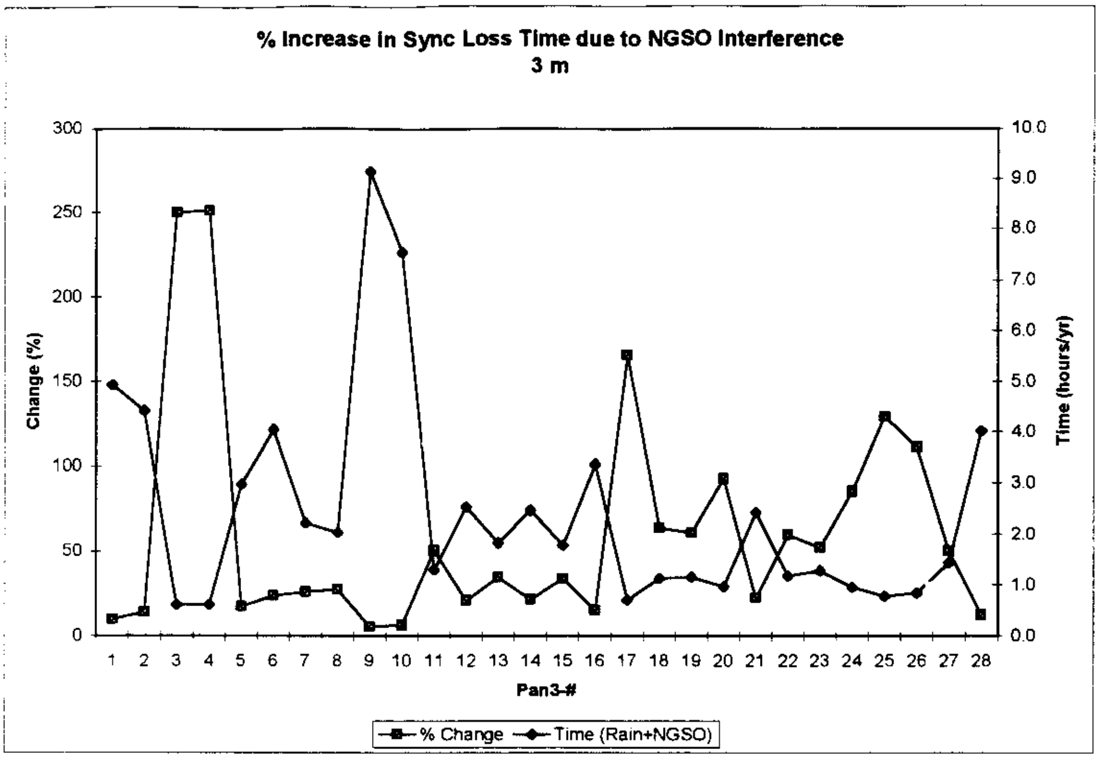

FIGURE 5.3-4

Increase in Sync Loss Time for 3 m Antenna

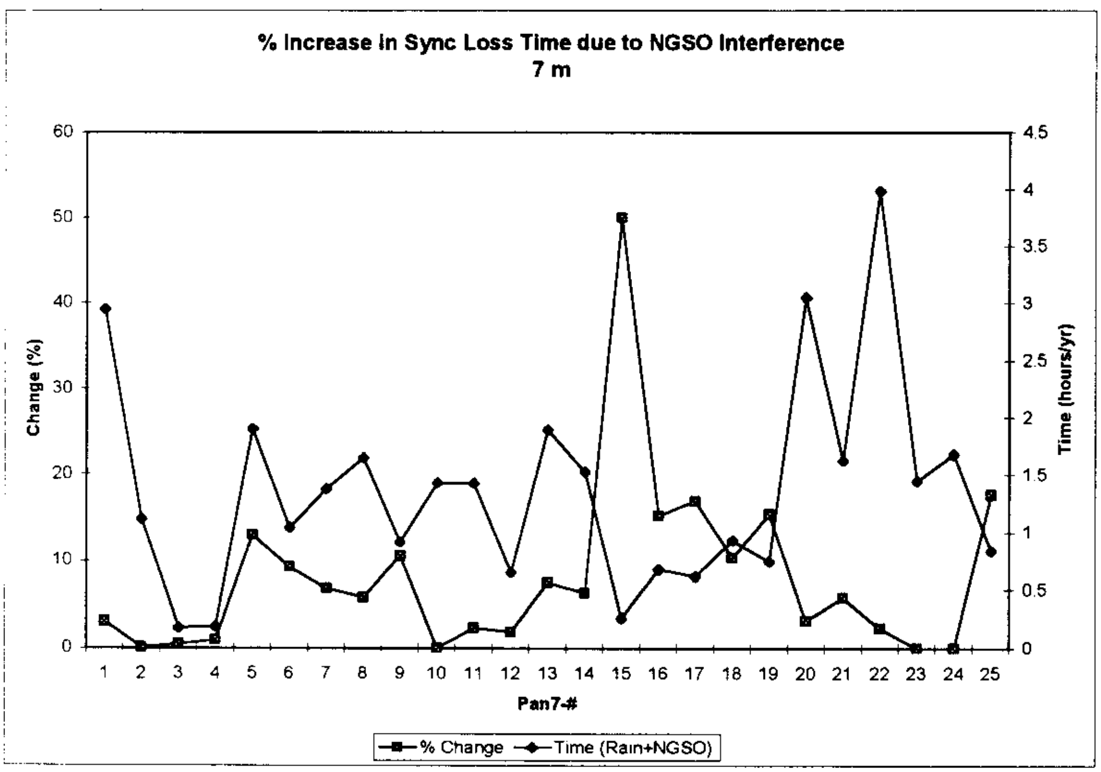

FIGURE 5.3-5

Increase in Sync Loss Time for 7 m Antenna

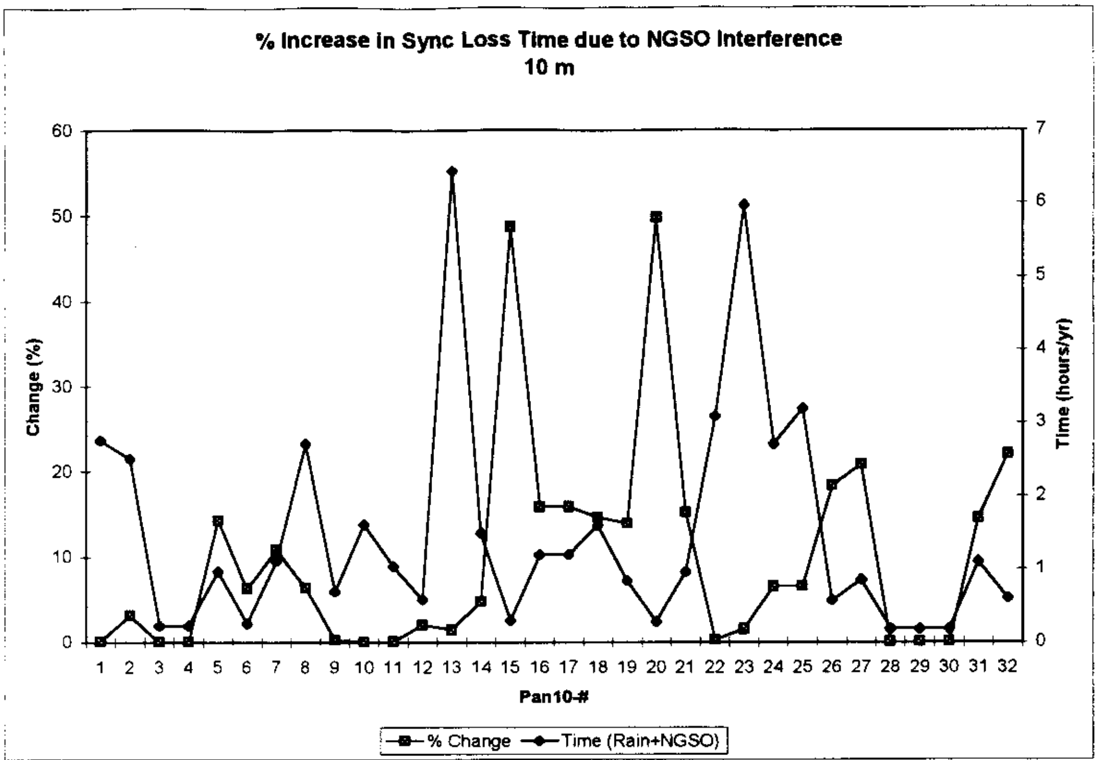

FIGURE 5.3-6

Increase in Sync Loss Time for 10 m Antenna

Table 3.3-1 shows the mean and standard deviation for the change in sync loss outage time with and without NGSO interference and total sync loss outage time due to NGSO interference. Due to the large %change in the 1.8 and 3 m antennas, it appears that the sync loss value for each mask may need to be tightened. This mask provides the most protection against synchronization loss.

TABLE 5.3-1

Mean and Standard Deviation for %Change and Time

Antenna Size	Mean (%change)	Std Dev (%change)	Mean (hours/year)	Std Dev (hours/year)
0.6	0.146	0.124	2.94	2.69
1.2	2.54	3.04	1.59	1.27
1.8	18.0	28.8	2.68	2.27
3	61.1	66.4	2.46	2.08
7	8.22	10.4	1.36	0.910
10	9.81	12.6	1.49	1.54

6 Margin Increase

In order to estimate GSO burden, document US WP4A/67 assumed that sensitive links might have to carry 1 dB of margin in order to overcome NGSO interference. The following analysis shows the decrease in sync loss time due to the extra margin for the proposed masks.

6.1 Analysis A with 1 dB of Extra Margin

Figures 6.1-1 through 6.1-3 show the total sync loss outage time per year with NGSO interference. One dB of extra margin has been placed on each sensitive link.

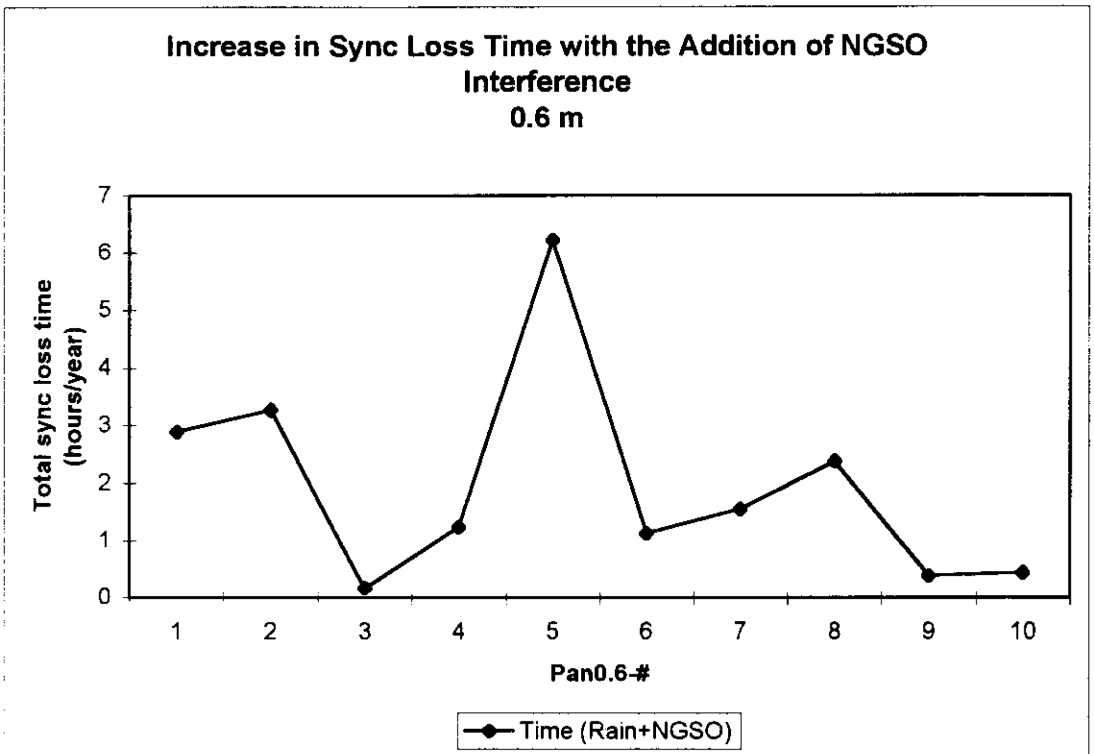

FIGURE 6.1-1

Increase in Sync Loss Time for 0.6 m Antenna

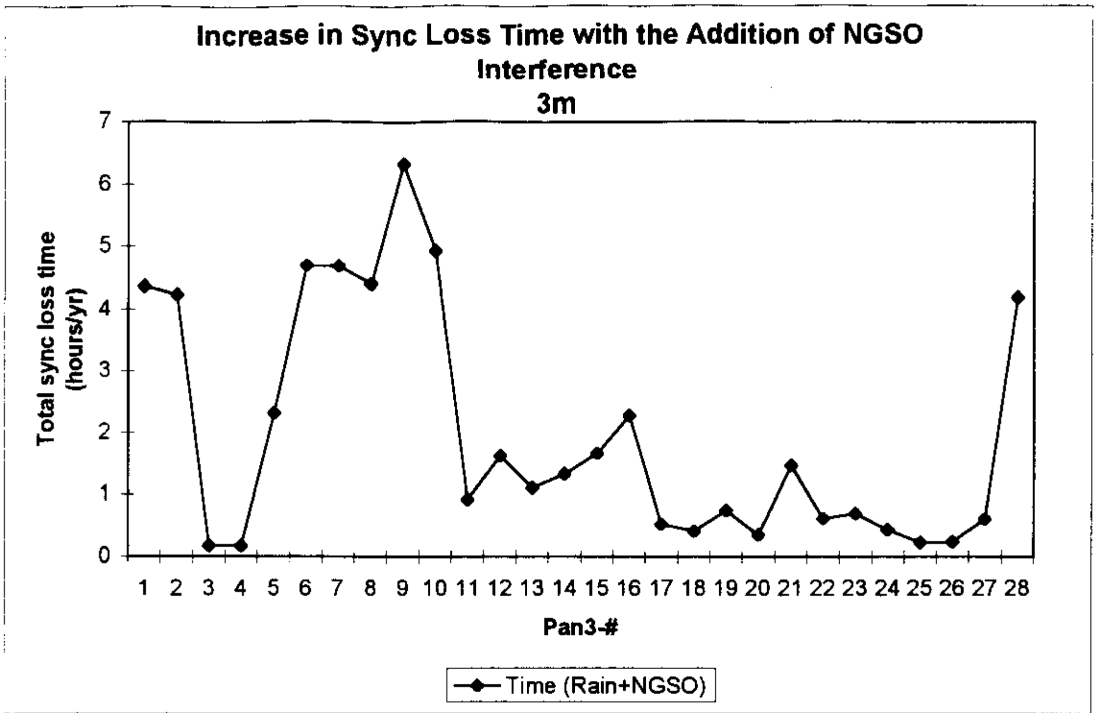

FIGURE 6.1-2

Increase in Sync Loss Time for 3 m Antenna

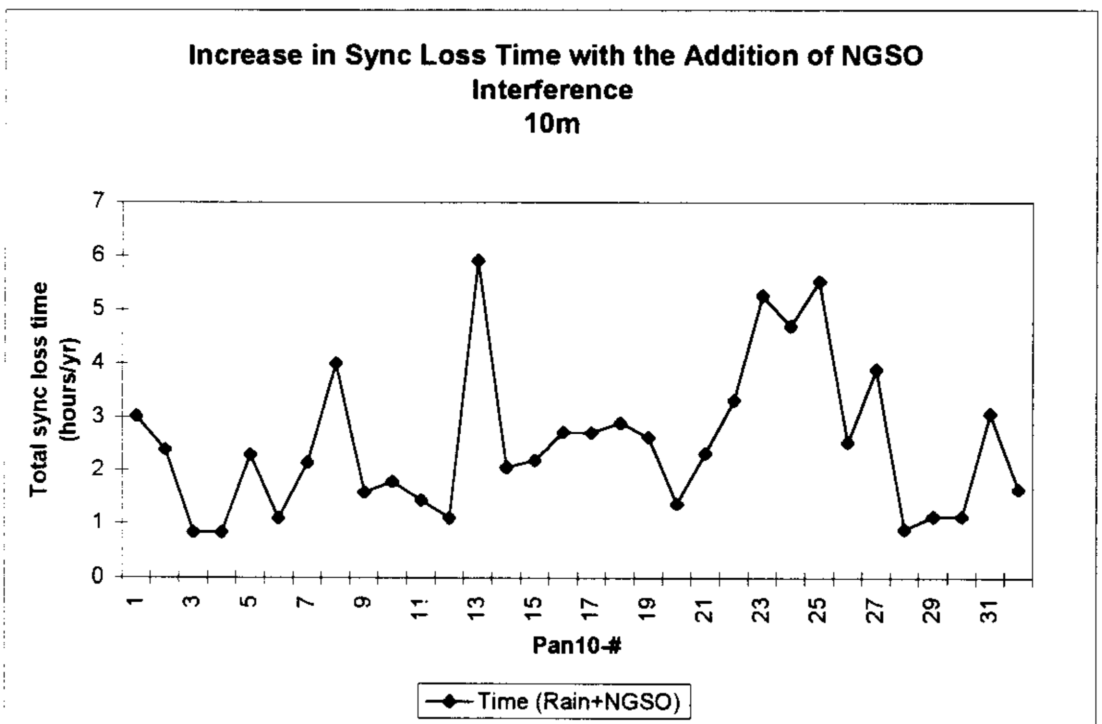

FIGURE 6.1-3

Increase in Sync Loss Time for 10 m Antenna

Table 6.1-1 shows the mean and standard deviation for the total sync loss outage time due to NGSO interference.

TABLE 6.1-1

Mean and Standard Deviation for Time

Antenna Size	Mean (hours/year)	Std Dev (hours/year)
0.6	1.97	1.83
3	1.99	1.89
10	2.52	1.43

6.2 Analysis B with 1 dB of Extra Margin

Figures 6.2-1 through 6.2-2 show the total sync loss outage time per year with NGSO interference. One dB of extra margin has been placed on each sensitive link.

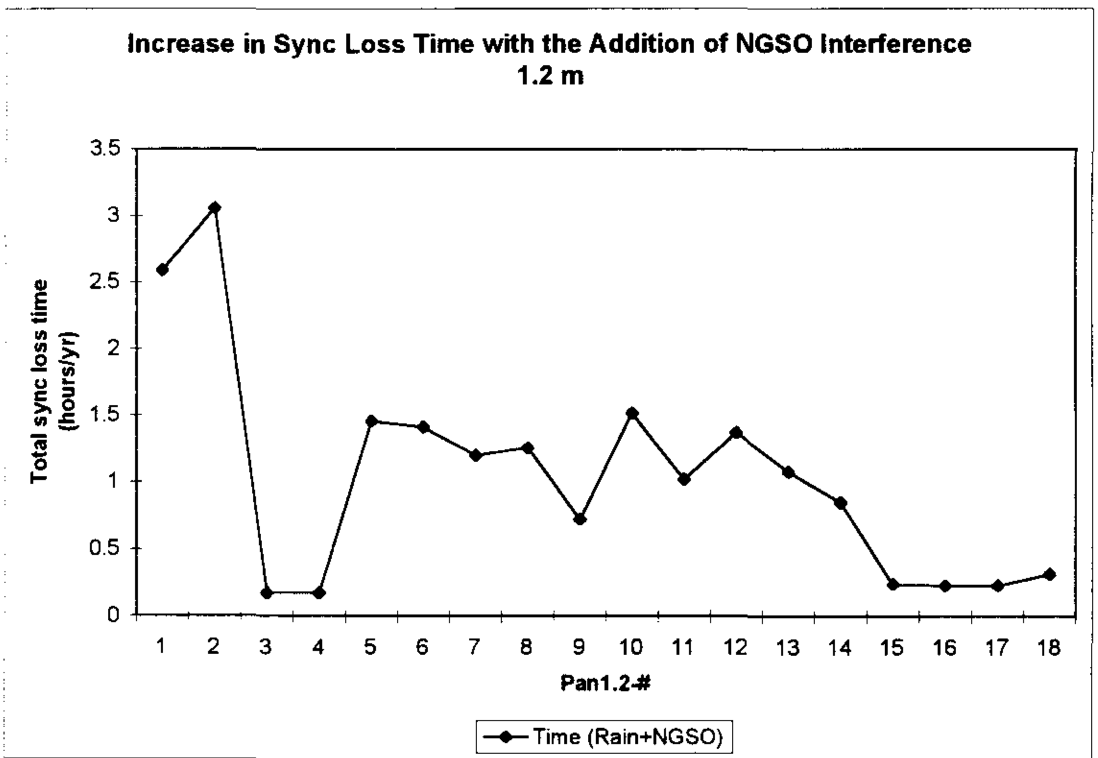

FIGURE 6.2-1

Increase in Sync Loss Time for 1.2 m Antenna

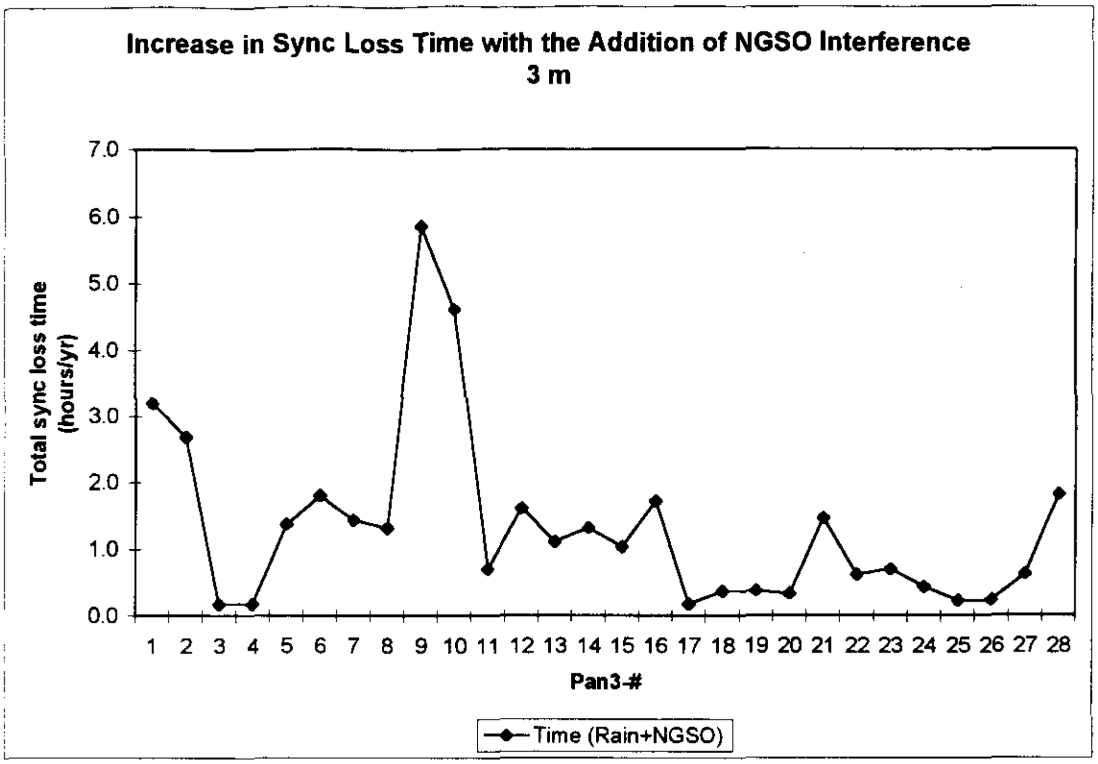

FIGURE 6.2-2

Increase in Sync Loss Time for 3 m Antenna

Table 6.2-1 shows the mean and standard deviation for the total sync loss outage time due to NGSO interference.

TABLE 6.2-1

Mean and Standard Deviation for Time

Antenna Size	Mean (hours/year)	Std Dev (hours/year)
1.2	1.05	0.81
3	1.34	1.35

6.3 Analysis C with 1 dB of Extra Margin

Figures 6.3-1 through 6.3-6 show the total sync loss outage time per year with NGSO interference. One dB of extra margin has been placed on each sensitive link.

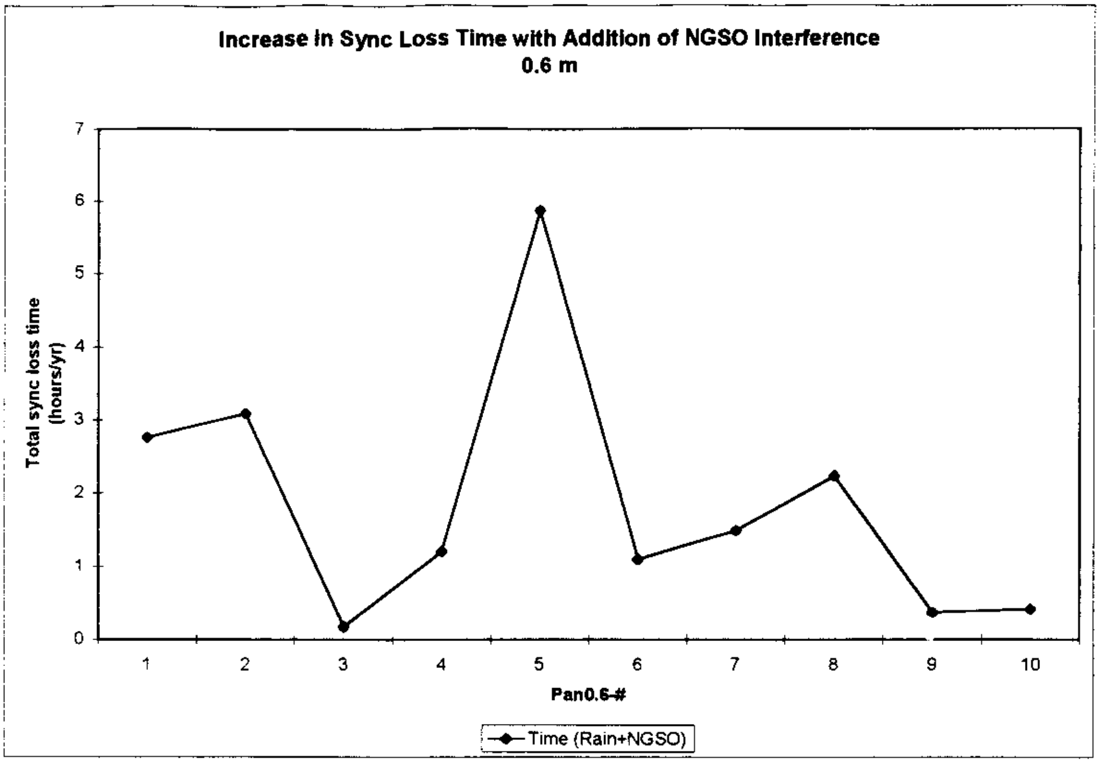

FIGURE 6.3-1

Increase in Sync Loss Time for 0.6 m Antenna

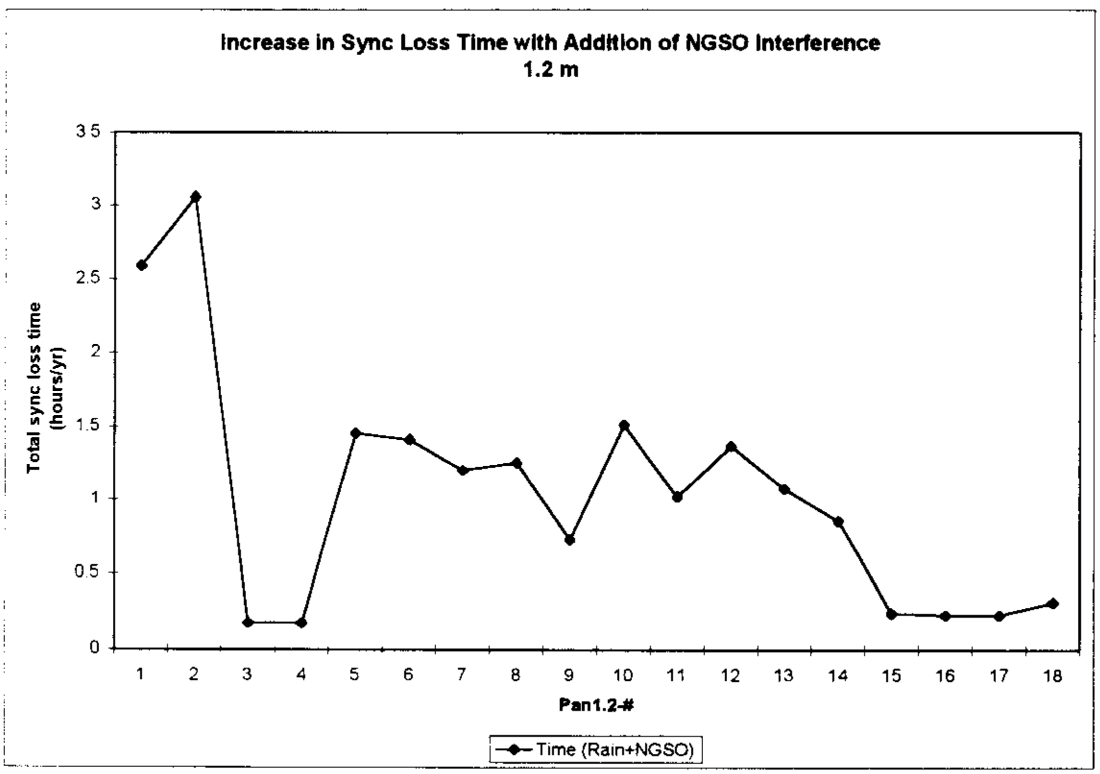

FIGURE 6.3-2

Increase in Sync Loss Time for 1.2 m Antenna

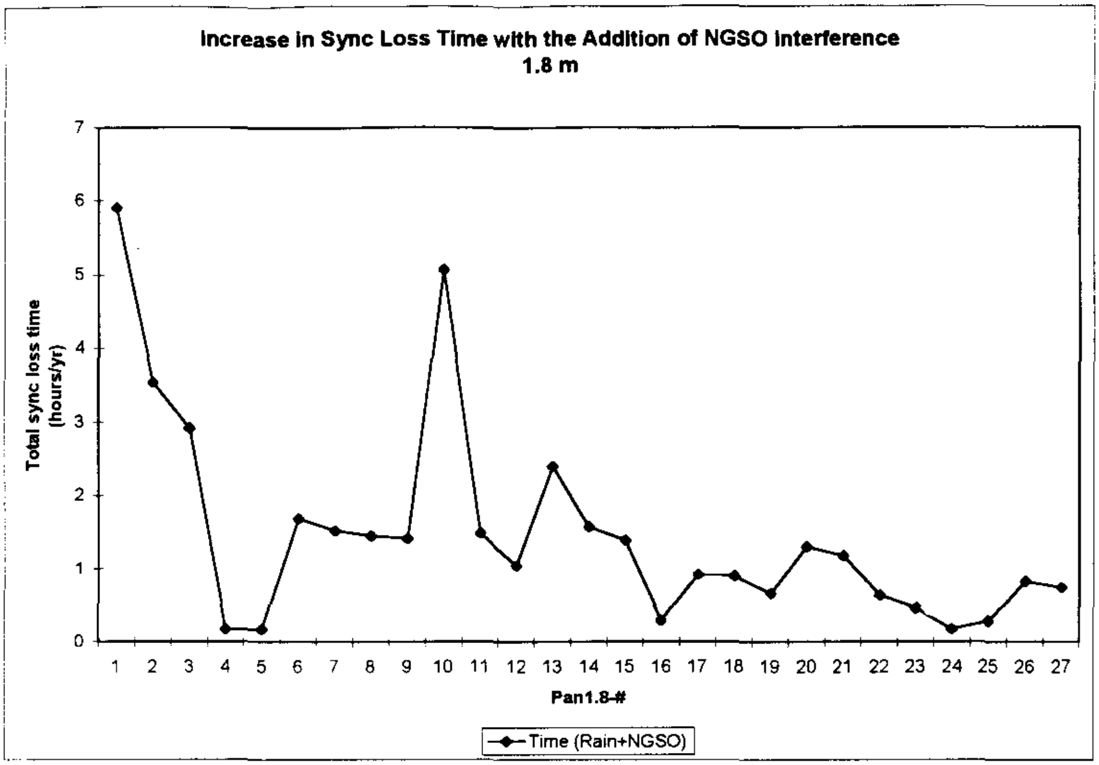

FIGURE 6.3-3

Increase in Sync Loss Time for 1.8 m Antenna

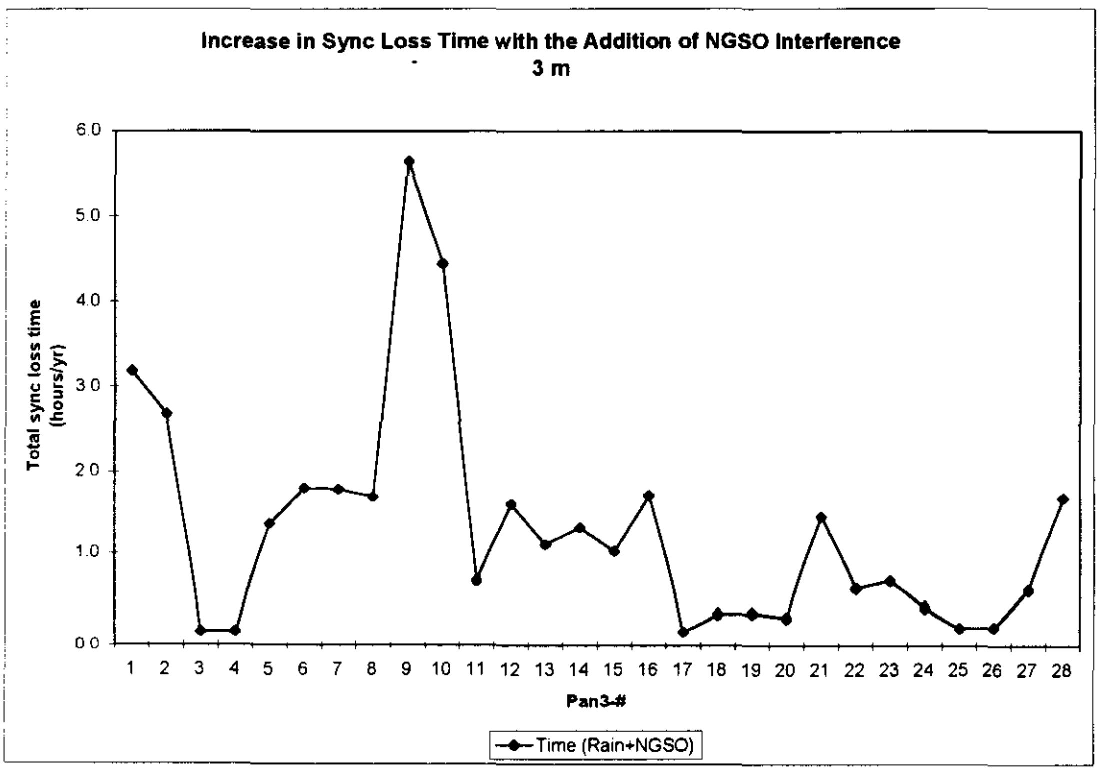

FIGURE 6.3-4

Increase in Sync Loss Time for 3 m Antenna

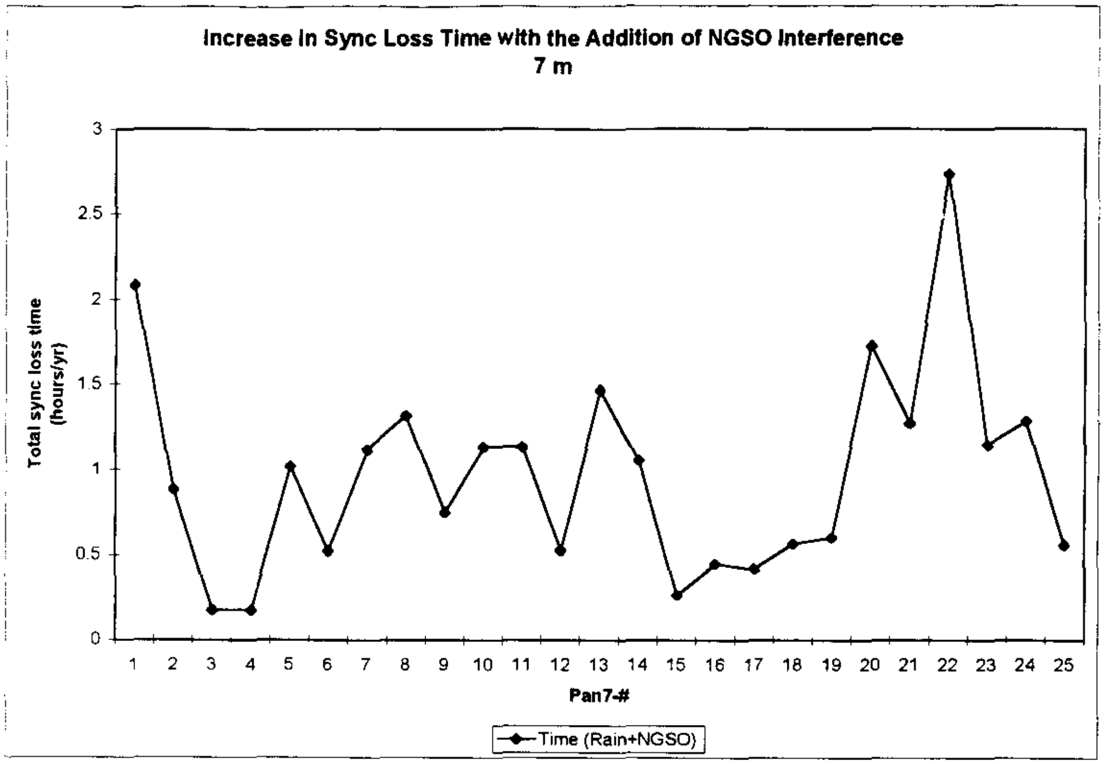

FIGURE 6.3-5

Increase in Sync Loss Time for 7 m Antenna

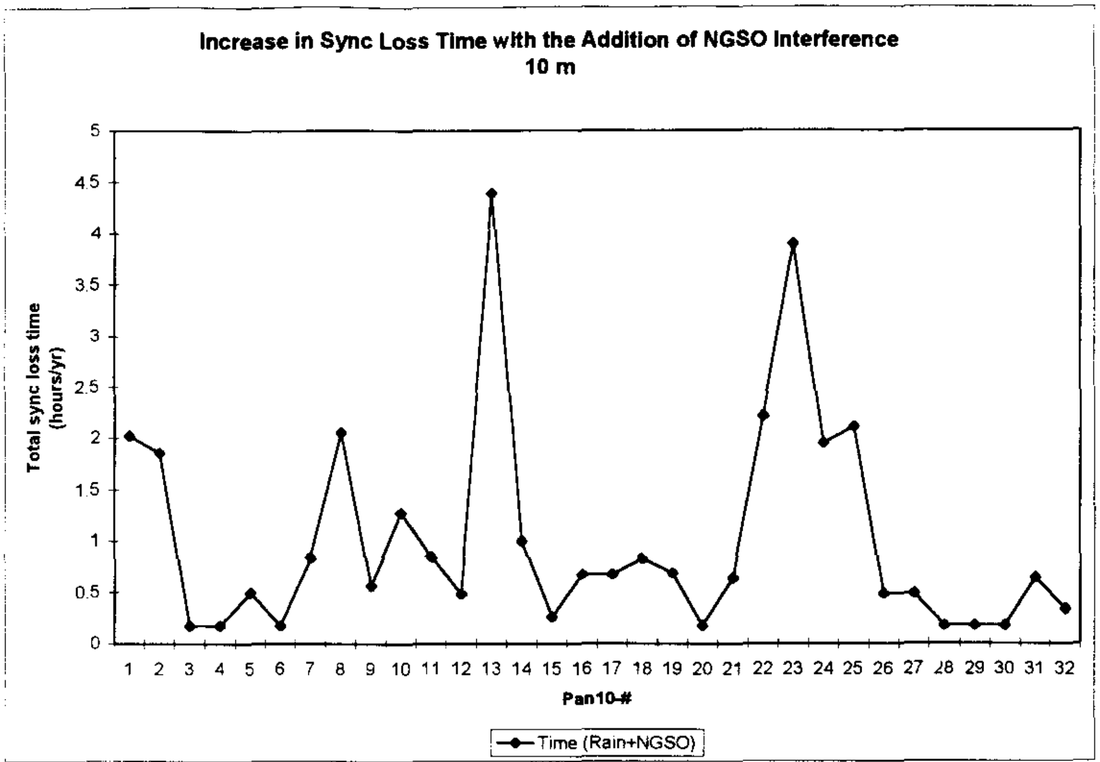

FIGURE 6.3-6

Increase in Sync Loss Time for 10 m Antenna

Table 6.3-1 shows the mean and standard deviation for the total sync loss outage time due to NGSO interference. Again, this mask provides the most protection against synchronization loss.

TABLE 6.3-1

Mean and Standard Deviation for %Change and Time

Antenna Size	Mean (hours/year)	Std Dev (hours/year)
0.6	1.87	1.73
1.2	1.05	0.81
1.8	1.49	1.41
3	1.34	1.31
7	0.975	0.607
10	1.03	1.05